TOOL STONES FROM THE PUNCHAW LAKE VILLAGE SITE (FiRs-1), NECHAKO PLATEAU, BRITISH COLUMBIA, CANADA

By

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ABSTRACT

Progress in petrography and chemical characterization of igneous lithic material and artifacts have been used to infer culture history, land use patterns, and potential exchange networks across British Columbia in recent years. This thesis examines the petrographic and geochemical characteristics of igneous flake samples collected from the Punchaw Lake Village site (FiRs-1), located west of Quesnel, British Columbia. The flakes are primarily composed of trachydacite and dacite of one or more unknown provenances. The primary objective of this study was to determine the possible sources of these igneous materials used in the production of the artifact assemblage. Three analytical techniques were employed to determine the physical composition of the specimens: (1) petrographic descriptions of the macroscopic and microscopic characteristics; (2) whole sample chemistry (major elements by inductively coupled plasma emission spectrometry [ICP-ES]; and (3) trace and rare earth elements by inductively coupled plasma mass spectrometry [ICP-MS]. The geochemical data were subjected to multidimensional scaling and hierarchical cluster analysis to aid the interpretations of the results. Results indicate that the lithic sample from Punchaw Lake Village site originates from more than one rock type, suggesting that the site inhabitants may have engaged in exchange and/or movement throughout the Nechako Plateau.

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My warm thanks to the Nazko and Lheidli T'enneh First Nations for the opportunity to examine the artifact assemblage from the Punchaw Lake Village site.

The Interior Plateau of northern and central British Columbia is archaeologically one of the least known regions of North America.

Charles E. Borden, 1952

The west-central and northern area of British Columbia is the most under-studied archaeological region in the province.

Matson and Magne, 2008

The Pre-Contact cultures of Subarctic British Columbia have received little published attention.

Fladmark, 2009

CHAPTER 1: INTRODUCTION

1.1 The Problem

Numerous geochemical studies have examined the selection, usage, and transportation of toolstones within and among hunter-gatherer communities. Analytical techniques used by geologists have also advanced archaeological efforts to identify and classify rock types, and origin of toolstone artifacts (e.g., lithic flakes, scrapers, cutting tools, drills, and projectile points) (Bakewell 2000; Bakewell and Irving 1994; Evans and Wilmeth 1971; Godfrey-Smith 1985; Heffner 2010; Magne 1979; Mallory-Greenough, Baker, and Greenough 2002; Nelson and Will 1976; Richards 1988; Smith 2004). The Nechako Plateau has had little or no formal tool stone analyses of artifact assemblages manufactured from varieties of rock (e.g., chert, dacite, trachydacite, obsidian and rhyolite and others) (Heffner 2010, but see Watson 2011 for an exception), and sourcing of these materials with the exception of obsidian (Carlson 1994), is poorly understood. This study focuses on the Punchaw Lake Village, an archaeological site in the north central interior of British Columbia. The goal is to utilize a combination of analytical techniques to better understand the significance of igneous tool stone selection.

Tool stone studies provide insight into the manufacture of tools as well as land use strategies employed by the hunter-gatherers who utilized these raw materials. Briefly, these studies require several approaches including the identification of: (a) primary and/or secondary provenances of tool stone; (b) range of provenances represented, through a regional-scale sampling of types of rock; (c) variability of individual

provenances; (d) spatial patterns of tool stone distribution within a study area; (e) temporal exploitation of provenances; and (f) interpretation on tool stone transport, based on spatial patterns over landscapes. In ideal situations all of the above should be goals for understanding use of lithic raw materials by hunter-gatherers in the past; however, data often do not exist to utilize all of these diverse aspects.

Little is known about the provenances of tool stones in the central interior of British Columbia, but as a starting point it is important to delineate whether or not igneous raw materials in sites such as Punchaw Lake were obtained from one or more sources. This thesis is an investigation into the variability represented in the igneous rock types in the artifact assemblage from the Punchaw Lake Village site (FiRs-1) in British Columbia. The goal is to identify whether samples represent one or more igneous rock types. Evidence of more than one rock type would suggest more than one provenance was exploited by hunter-gatherers through space and time in response to various factors. The use of one or more raw materials could be a response to cultural or individual selection of specific tool stone, seasonal movement, and methods of acquiring resources, exchange, and seasonal availability of tool stone, amongst other factors. To investigate the physical variation, the following null hypothesis is tested in this thesis:

H_o: *Tool stones found at Punchaw Lake Village site cannot be shown to be lithologically different.*

1.2 Background History

The Punchaw Lake Village site is located west of Quesnel, British Columbia (BC) Nechako Plateau. It is adjacent to Punchaw Lake, on the northwest bank of Tako Creek, which drains into the West Road (Blackwater) River. The site (FiRs-1) was initially

excavated by Dr. Knut Fladmark (1974) as part of a Simon Fraser University field school, and then further excavated by James Helmer (Helmer and Wilson 1975). Artifacts recovered during the 1974 field season were examined and analyzed by Pamela (Wilson) Montgomery as part of her Masters thesis (Montgomery 1978).

The site is at the juncture of two principal historic trails that extend outward into the Nechako Plateau, and they are of historical significance to a number of Carrier First Nations. The village site covers approximately 54,000 m^2, with 43 house platforms and 57 storage pits (Fladmark 1976). To date, Montgomery (1978) and Watson (2011) are the only studies of the artifact assemblage.

1.3 Approaches Used in the Study

The study utilizes a combination of analytical techniques to test whether one or more provenances are represented in a sample of flakes. They include: macroscopic visual analysis; petrographic (microscopic) analysis; analysis of major, trace, and rare earth elements (REE) using inductively coupled plasma emission spectrometry (ICP-ES) and inductively coupled plasma mass spectrometry (ICP-MS); and rock classification based on the element analysis.

1.4 Structure of Thesis

The thesis consists of seven chapters. Following this introductory chapter, Chapter 2 reviews the Nechako Plateau physiography and culture history of the Interior Plateau. Chapter 3 examines ethnohistoric and ethnographic exchange among Pre-Contact hunter-gather groups on the Canadian and Columbia Plateaus, and in Australia.

Chapter 4 summarizes geochemical studies of tool stone within BC, including techniques that have been used to identify rock types observed in both tool stone sources and in stone tools. Chapter 5 describes the sampling strategy and the methodologies used for the macroscopic, petrographic (microscopic) and geochemical analyses. Chapter 6 presents results from the various techniques, and interpretations based on a quantitative analysis. Chapter 7 summarizes the results of this study and provides conclusions and considerations for the future. The data generated from this study will contribute valuable information for our understanding of tool stone selection in central British Columbia, and to future studies on the provenancing and exchange of tool stone.

CHAPTER 2: REGIONAL GEOGRAPHY AND CULTURE HISTORY

2.1 Introduction

The Punchaw Lake Village site is located within the Nechako Plateau, the northernmost of three subdivisions of the Interior Plateau (Holland 1976, Howes 1977, Tipper 1971). The northern boundary coincides with the southern boundary of the Subarctic Culture Region of BC that extends into the Yukon Territory. A combination of geologic (e.g., tectonic and volcanic) and environmental (e.g., Quaternary glaciations) events created a landscape exposing raw material and natural resources that were used by Aboriginal people. Provenances of igneous (obsidian and dacite) and sedimentary (chert) rock produced raw material procured for stone tool manufacture throughout the region. Glaciers and glacial runoff eroded rock and soils to create tributaries and major watersheds that provide fresh water, salmon spawning streams, and natural travel routes through densely forested and rocky terrain.

Archaeological evidence suggests movement of Aboriginal people took place across the Interior Plateau over several millennia, as reflected in artifact assemblages interpreted as belonging to the Lochnore Phase and Plateau Pithouse Tradition (Richards and Rousseau 1987; Rousseau 2004, 2008). At Punchaw Lake in particular, projectile point types and radiocarbon dates delineate the chronology of the site. Much of the discussion on the artifact assemblage is taken from general descriptions of cultural periods based on sites further south in the Interior Plateau. To date, no culture history has been proposed specifically for the Nechako Plateau.

2.2 Geography of the Study Area

The Punchaw Lake Village site is located within the Blackwater District of the Nechako Plateau (Fladmark 1976). The immediate environment surrounding the site consists of forested rolling uplands and river valleys drained by the West Road, Nechako, and Fraser rivers. The site is situated adjacent to Punchaw Lake and the northwest bank of Tako Creek (See Figure 1). Punchaw Lake flows into Tako Creek, which drains into the West Road River.

The Nechako Plateau is an area of low relief, with gently rolling to hilly terrain, and isolated, rounded mountains with surface elevations generally ranging from 850 to 1500 m above sea level (a.s.l.) (Levson et al. 1998, Tipper 1971). Mountain ranges of the Plateau include the Quanchus, Fawnie, Telegraph, and Nechako, which are erosional remnants of monadnocks (Holland 1976, Tipper 1971). The region is bounded by the Columbia Mountains to the east, subdivided into the Cariboo, Monashee, Selkirk, and Purcell ranges; to the west by the Coastal Mountains, subdivided by the Hazelton Mountains; and to the north by the Skeena and Omineca mountains.

A relatively simple stratigraphy is found over much of the Nechako Plateau (Clague 2000). It is dominated by volcanic and sedimentary rocks of the Jurassic Hazelton Group and by volcanic rocks of the Tertiary Ootsa Lake and Endako Groups (Levson et al. 1998:16). These Tertiary lava flows cover older volcanic and sedimentary rocks of the Takla and Hazelton Groups and intrusive rocks of the Upper Jurassic and Cretaceous age (Holland 1976). The Tertiary volcanic rocks form round hills and, in places, floor the valleys with flat-lying or gently dipping lava flow. Lava flows

representing Chilcotin Group basalts underlie the central Interior Plateau between the Coast Mountains and Quesnel Highlands (Bevier 1982:4). The Nechako Plateau is primarily underlain by Stikinia (beneath younger volcanic cover), representing one of the peri-Laurentian terranes extending to its eastern edge at Cache Creek (Maurice Colpron, personal communication 2008; Colpron et al. 2007).

Repeated glaciation during the Quaternary Period eroded the bedrock topography as glaciers moved east-southeastward onto the Nechako Plateau from ice centers in the Skeena, Hazelton, Coast, and Omineca Mountains (Plouffe and Levson 2001; Stumpf et al. 2000). As a result, glacier landforms on the Plateau are extensive and include well-developed flutings and drumlinoid ridges. Much of the Plateau is blanketed by till from the last glaciation. Glacial deposits and landforms typical of stagnating ice include kame and kettle topography, large esker complexes, extensive glaciolacustrine sediments, glaciofluvial deposits, and meltwater channels (Levson et al. 1998:16).

2.3 Culture History

The first occupation in the northern portion of the Interior Plateau was once thought to have been at ca. 4,000 years before present (BP) (Stryd and Rousseau 1996; Rousseau 2004, 2008). However, sites found within the past 15 years in northeast BC, such as Charlie Lake Cave [approximately 10, 425 ^{14}C yr BP based on the average of four radiocarbon dates] (Fladmark 1996: 16) and the Landels site [8400 ^{14}C yr BP] (Stryd and Rousseau 1996: 184) in the southern portion of the Interior Plateau, provide evidence

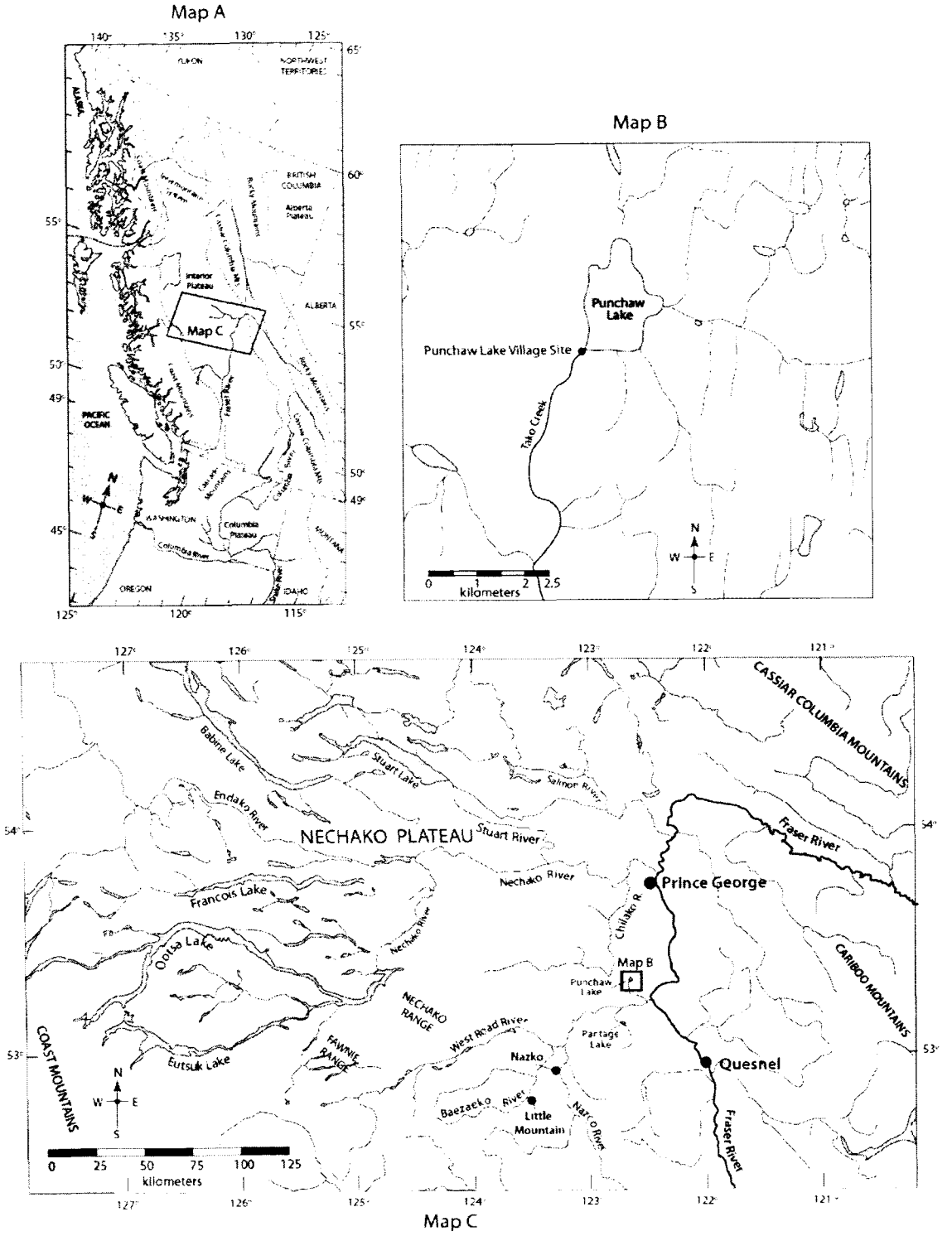

Figure 1: Maps of Punchaw Lake Village Site and surrounding region.

for much older occupations. In closer proximity to Punchaw Lake, the artifact assemblage at the FlRq-013 site in Prince George suggests an early occupation on the Nechako Plateau. Two radiocarbon samples obtained from charcoal found in hearth features gave uncalibrated ages of 8770 ± 60 and 7970 ± 50 BP (Burford et al. 2008: 294).

No archaeological research or fieldwork was conducted in the central and southern Interior Plateau of British Columbia (BC) prior to the beginning of the 1950s (Magne 1985). Initial fieldwork on the Nechako Plateau began with projects directed by Borden (1952), and the culture history continues to develop primarily through Cultural Resource Management practices within BC today (Heffner 2010). Fieldwork by Fladmark in 1973 (1974, 1976) and Helmer and Wilson (Montgomery) in 1974 (1975) at the Punchaw Lake Village site contributed new information regarding the antiquity and nature of Aboriginal life on the Nechako Plateau. The Punchaw Lake Village site appears to have been occupied for at least 4,000 years by two or more ethnolinguistic groups (i.e., Salishan and Athapaskan), based on projectile point styles and key-shaped unifaces found on the site (Fladmark 2009). Athapaskan influences from the Subarctic culture region in the Yukon and northern BC predominate findings from the last 1,000 years.

Knut Fladmark (2009) suggests projectile points found at the Punchaw Lake Village site fall typologically into all three of the cultural horizons of the Plateau Pithouse Tradition as defined by Richards and Rousseau (1987). Richards and Rousseau utilized projectile points from Punchaw Lake and elsewhere to reconstruct the cultural sequences of the Interior Plateau for the last 4,000 years. Cultural sequences identified at Punchaw Lake include the Lochnore Phase, and Shuswap, Plateau, and Kamloops horizons, which constitute the Plateau Pithouse Tradition. These cultural sequences are characterized by

semi-sedentary pithouse dwellings, hunter-gatherer activities, and logistically organized band-level societies that relied heavily on anadromous fish for subsistence (Fladmark 2009; Richards and Rousseau 1987; Stryd and Rousseau 1996; Rousseau 2004). Dates for the following cultural sequences are given in radiocarbon (^{14}C) years BP (Rousseau 2004).

2.4 Lochnore Phase (ca. 5000 – 3500 ^{14}C yr BP)

The Lochnore Phase is characterized by various artifacts and technological traits (Rousseau 2004:13), such as large and medium sized lanceolate, leaf-shaped, formed bifacial points/knives with wide, shallow to moderately deep opposing side notches, heavy basal edge grinding, and pointed or convex bases (i.e., Lochnore side-notched point). The Lochnore phase is defined by a variety of stone tools (e.g., scrapers, microblades, unifacial reduced and notched pebble tools) that are distinct to this time period (Rousseau 2004:13). Various raw materials were procured for tool manufacture, such as igneous rock (i.e., dacite and, less frequently, obsidian) and silicate raw material (i.e., chert and chalcedony).

Habitation sites were often small to medium in size, suggesting a relatively short-term occupation period. In some cases, large habitation sites indicate repeated occupations (Rousseau 2004, Stryd and Rousseau 1996). Many of these sites are located on the edges of flat upper terraces along the sides of main river valley bottoms, especially at or near junctures of major tributary creek valleys; field camps have been found in mid-altitude valley beside small lakes and streams, which suggest occupations by groups of 10 to 20 persons for short periods (Rousseau 2004). Organic artifacts include bone splinter

unipoints, antler wedges, rodent incisors and drilled animal teeth. Marine shell beads suggest Aboriginal peoples transported and/or exchanged resources between coastal and Interior Plateau people (Rousseau 2004, Stryd and Rousseau 1996).

"Burial 2" site at Punchaw Lake was a flexed adult interment in an ovate pit excavated from beneath the lowest hearth stratum of House-Platform 1. An age of 3,980 ±100 ^{14}C yr BP (GAK-4907) came from carbonized organic material collected near the skull (Fladmark 1974, 2009). If this ^{14}C age closely constrains the age of the skull it places the burial within a late Lochnore Phase (Mike Rousseau, personal communication, 2008). The ^{14}C age should be considered with caution until additional fieldwork is undertaken at this site.

2.5 Shuswap Horizon (ca. 3500 – 2400 ^{14}C yr BP)

The Shuswap Horizon is characterized by distinct varieties of projectile point styles (Rousseau 2008). These points display a relatively high degree of stylistic variability, suggesting their intended use with spear or dart-thrower technology (Richards and Rousseau 1987: Figure 16; Rousseau 2004, 2008). The presence of dart-throwers is known in British Columbia, such as one made on elk antler (see Figure 2) from the bottom of Quiltanton Lake, with an uncorrected age of 1950 ±100 ^{14}C yr BP (SFU RIDDL 1141) (Keddie 1988, 1988a, 1988b; Grant Keddie, 2010 Personal Communication), and possible dart-thrower weights (Duff 1956). Recent archaeological evidence suggests the usage of dart-throwers in the Columbia Plateau from 10,800 to approximately 1,000 ^{14}C yr BP (Ames et al. 2010). The bow and arrow replaced the dart-thrower at about 1500 BP (Carlson 1994). The dart-thrower acts as an extension of the

individual's arm, contributing to the force and momentum generated to throw a dart (Hutchings and Brüchert 1997).

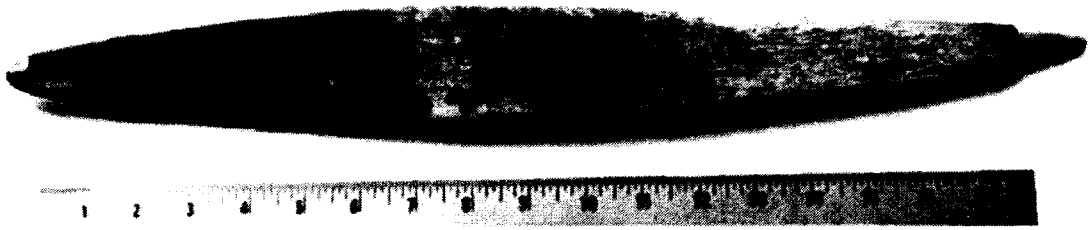

Figure 2: Quiltanton Lake dart-thrower (EcRg-Y-1).
(Photo reprinted by permission of Grant Keddie ©, Royal British Columbia Museum, 2010).

One distinctive artifact type that persists from the Shuswap Horizon to the end of the Plateau Horizon (ca. 3300 to 1200 ^{14}C yr BP) is a unique key-shaped formed uniface/biface, which is not found in large numbers on archaeological sites in the Subarctic and Interior Plateau (Richards and Rousseau 1987; Rousseau 1992). Formed scrapers do exist, but they are considered rare and usually in the style of small thumbnail endscrapers (Richards and Rousseau 1987). The most commonly found stone tools are unifacial and bifacial tools that demonstrate a relatively modified composition of workmanship and technological sophistication, when compared to later horizons (Richards and Rousseau 1987). Locally available tool stone such as dacite, trachydacite, obsidian, chert, and chalcedony were procured and manufactured into a variety of stone tools (Richards and Rousseau 1987).

Other cultural characteristics of the Shuswap Horizon include bone and antler artifacts, such as flat, discoidal beads with single circular perforations; bone bracelets; bilaterally barbed bone points and harpoon valves; and awls (Richards and Rousseau

1987). Evidence of artwork consists of a possible zoomorphic bear head on a pestle dating ca. 3000 ^{14}C yr BP (Richards and Rousseau 1987). Large housepit depressions lack raised earth rims, are circular to oval in plan, are flat bottomed with steep walls, and the floors are rectangular in plan (Richards and Rousseau 1987).

Richards and Rousseau (1987) suggest subsistence during the Shuswap Horizon focused on ungulates and birds, as well as fresh water mussels, salmon, trout, and other fresh water species. The floral subsistence is likely to have been based on seasonally available plants, although there is no evidence of this at excavated sites.

Burials of the Shuswap Horizon indicate individuals were interred in a flexed position below house floors and lacked grave inclusions. At one archaeological site, red ochre was associated with a number of burials, while one burial was covered with boulders (Richards and Rousseau 1987).

2.6 Plateau Horizon (ca. 2400 – 1200 ^{14}C yr BP)

The Plateau Horizon is characterized by bilaterally barbed projectile points with either corner or basal notches, which appear to be designed for tipping a variety of hunting implements (i.e., spears, dart-thrower darts, and arrow shafts) and are unique due to their style or type (Richards and Rousseau 1987: Figure 19; Rousseau 2004, 2008). Large projectile points were manufactured throughout the Plateau Horizon, while small points began to appear sometime between ca. 1700 to 1500 ^{14}C yr BP. The sophistication of this lithic technology is demonstrated by the workmanship of bifaces and projectile points that are often large, thin, and symmetrical with well-controlled pressure flaking (Richards and Rousseau 1987). Additional point styles that appear less frequently include

lanceolate, leaf-shaped, corner-notched barbless points, and a variety of stemmed projectile points.

Other common forms of artifacts are key-shaped unifaces/bifaces; microblades and cores; and native copper and ground stone artifacts. Bone, antler, shell, animal tooth materials increase in use over time as evident in the number of harpoons, along with pendants, beads, and incisor tools recovered from archaeological sites. Incised objects, sculptures, and ground stone tools such as nephrite celts, hand mauls, and slate artifacts are rare at the beginning of the Plateau Horizon, but increase in use by ca. 1900 ^{14}C yr BP (Richards and Rousseau 1987). Steatite was used in the manufacture of pipes, bowls, and small ornaments and sculptures (Rousseau 2004: 18).

Housepit depressions lack raised earth rims, they are circular to oval in plan, and contain a central hearth feature, which may indicate that a smoke hole was present at the apex of the roof that may also have served as the entrance to the house. Housepit walls were usually steep, with a flat floor, resulting in a basin-shaped profile, while post holes and roof insulation zones indicate the use of wooden superstructures covered with earth, similar to known ethnographic house styles (Richards and Rousseau 1987).

Grave goods found within burials were uncommonly found in different types of sites (Richards and Rousseau 1987). Grave goods may indicate the direction of distribution of exchanged resources amongst varying hunter-gatherer groups living in the Interior and Subarctic plateaus. Examples of exchanged commodities include nephrite, coastal shells, and tool stone manufactured into a variety of implements. In fact, dogs appear during this horizon where they may have filled many roles: as companions, for protection and hunting, and as pack animals used to carry goods whether for domestic or

for exchange purposes (Rousseau 2004). Evidence of subsistence was determined using stable isotope (δ ^{13}C) analysis of human skeletons, which demonstrated approximately 60 percent of the dietary protein had a marine origin (Chisholm et al. 1983).

2.7 Kamloops Horizon (ca. 1200 – 200 ^{14}C yr BP)

The Kamloops Horizon spans ca. 1200 to 200 ^{14}C yr BP (Richards and Rousseau 1987; Rousseau 2004, 2008). The Kamloops side-notched arrow point is characterized by a small triangular arrow point with small, narrow, opposing side-notches; straight to slightly convex or concave basal margins; and the complete absence of corner-notched points after ca. 1000 ^{14}C yr BP (Rousseau 2004:19). A distinct variant is the Kamloops multi-notched point, believed to date between ca. 400 to 100 ^{14}C yr BP. Multiple notches occur along one lateral blade margin, with a slightly larger overall size than the Kamloops side-notched arrow point (Richards and Rousseau 1987; Rousseau 2008). The well-known Kavik and Klo-kut points (See Figure 3), originating from Alaska and the Yukon, are found in association with Kamloops side-notched points (Pokotylo and Mitchell 1998) in territory occupied by Athapaskan Carrier and Chilcotin speakers (Fladmark 2009; Richards and Rousseau1987:45). Projectile point styles have been used both as indicators of migration and to differentiate between Salish- and Athapaskan-speaking cultures in the Interior Plateau (Magne and Matson 1982, 1987, 2010; Matson and Magne 2004, 2008).

Housepits vary in size and shape (i.e., oval, circular, rectangular, or square in plan) with prominent raised earth rims. Side entrances are evident in rectilinear housepits,

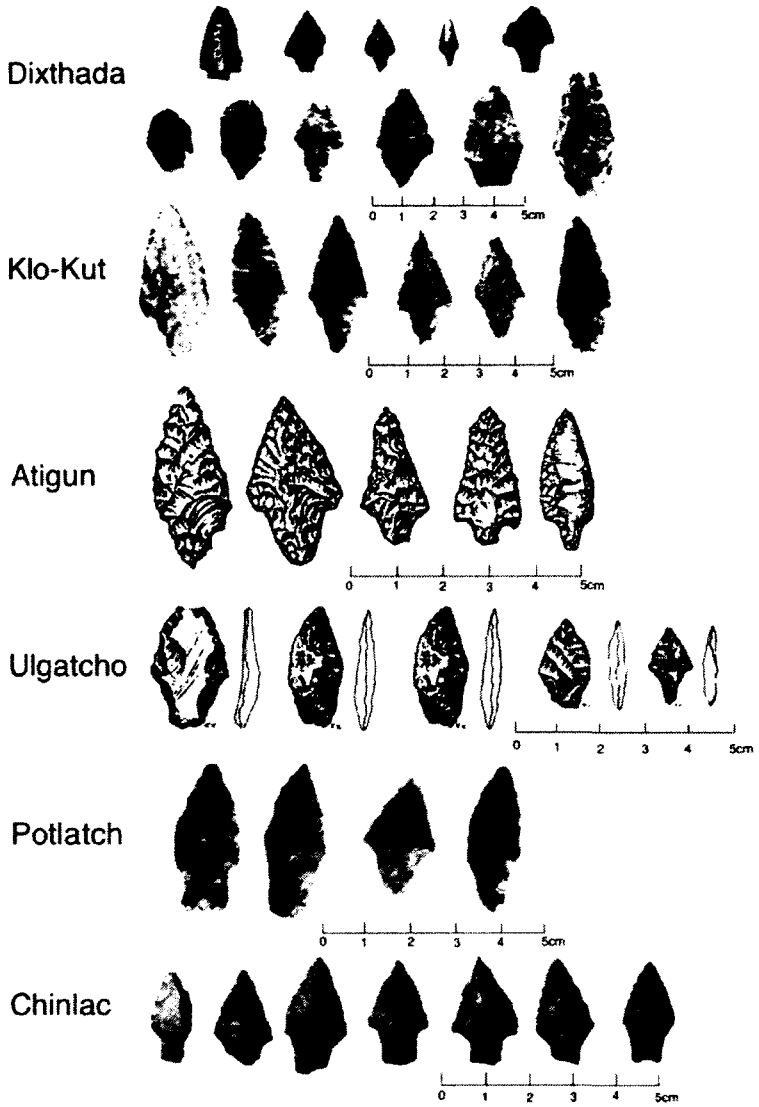

Figure 3: Kavik points from Dixthada, Klo-kut, Atigun, Ulkatcho, Potlatch, and Chinlac sites. Reprinted by permission of Kris Foreyt ©.

with remains of passageways between housepits found at one site (Richards and Rousseau 1987). Archaeological evidence indicates roof insulation deposits are usually thin or absent, in particular for rectilinear housepits, suggesting light pole and mat structures. Substantial post-holes in excavated rectilinear housepits further suggest light roof structures. Circular and oval housepits are more similar to ethnographically

described pithouses, which have substantial wooden superstructures covered with earth for insulation (Richards and Rousseau 1987). Central hearths are found in most housepits with cooking and storage pits often located within houses near floor/wall junctures (Richards and Rousseau 1987).

Biface technology is similar to that of the Plateau Horizon: "pentagonal formed bifaces are distinct for this horizon, and formal tools demonstrate more time/effort expended using pressure removal techniques with no evidence for microblade technology" (Richards and Rousseau 1987). Ground stone tools made from a high quality tool stone (i.e., slate, nephrite, and steatite) that demonstrate an increase in sedentary lifestyle, inferred from the time and energy spent to create zoomorphic and anthropomorphic forms (Richards and Rousseau 1987).

Other types of cultural material include native copper for decoration, bark artifacts for containers, lining for storage pits, woven basket containers, and plaited sagebrush bark mats. There is an increase in the variety and use of bone, antler, and tooth artifacts in comparison to the Plateau Horizon, with incised decorations (i.e., geometric patterns of parallel lines, ticks, and circles and dots) found more commonly on bone than antler artifacts within the Kamloops Horizon (Richards and Rousseau 1987). Decorated dentalium shell was also found (Richards and Rousseau 1987).

Burial practices vary, with the dominant pattern of primary flexed interment in unmarked shallow pits. Other burial techniques include wooden cist inhumations marked with rock cairns, multiple tomb burials, and talus slope burials. In some cases, fires had been built over the graves. Evidence of birch bark sheeting, tule matting, and cordage suggest that body wrapping and binding were a common burial practice (Richards and

Rousseau 1987). Variability of individual wealth and/or social status is suggested from the types of valuables occasionally found as grave goods. These are formal artifacts, made from local and/or imported raw materials, which demonstrate time and energy spent in collecting, exchanging, transporting, and manufacturing the material into a final product. This suggests interregional exchange was significant during the Kamloops Horizon for items such as dacite or trachydacite, nephrite celts, ground slate tools, steatite carvings, whalebone, and coastal shells (Hayden 2000; Richards and Rousseau 1987).

Evidence for subsistence is seen in sophisticated fishing technology, such as bone and antler leisters, unilaterally and bilaterally barbed points, harpoons and composite toggling harpoons, possible fish hooks barbs, and small bipoints resembling those used by the ethnographic Shuswap and Thompson (Richards and Rousseau 1987). Bow and arrow hunting technology is evident from the ubiquitous arrow-sized projectile point; the exploitation of root resources is evident from antler digging stick handles and a dated root-roasting oven (Richards and Rousseau 1987).

CHAPTER 3: EXCHANGE AND HUNTER-GATHERER SOCIETIES

3.1 Introduction

The Punchaw Lake Village site is located at the juncture of two historic trails that cross the landscape of the Nechako Plateau, inter-connecting with trail networks leading to the Subarctic, Coast, Plains, and Columbia Plateau Culture Areas. Dentalium shell used as a decoration and currency amongst Aboriginal peoples (Barton 1994) and widely exchanged across the Pacific Northwest and into the Interior Plateau (Galm 1994; Teit 1900, 1906, 1909) is also present at Punchaw Lake. The presence of raw materials originating far outside the Nechako Plateau reflects communication, transport and exchange of goods amongst Aboriginal people across the landscape. The lack of ethnographic or ethnohistoric documentation on exchange in the north central Interior of British Columbia makes it difficult to understand the mechanics of Aboriginal exchange prior to Contact. Observations from other areas, however, can provide potential analogues.

Aboriginal peoples in the interior of British Columbia are known to have transported and exchanged resources via trails across large portions of landscape that are sometimes parallel to major watersheds and their tributaries. Resources exchanged included a variety of raw material (e.g., stone, wood, horn, bone, shell), and foods (e.g., salmon, oolichan oil, elk, moose, deer, and berries). In addition exchange likely was a key mechanism to transmit and receive cultural information across the landscape.

There are very few examples of exchange in the adjacent Pacific Northwest Culture Area, and they were recorded long after first contact with Europeans, when

impact to traditional life ways was obvious. For example James Teit (1900, 1906, and 1909) observed that by the beginning of the 20th century stone tool manufacturing was becoming a rare occurrence, or non-existent in the southern Interior Plateau. It is difficult to gauge the nature of the changes to exchange that occurred with Contact. Given the little documentation on pre-Contact forms of exchange in British Columbia, it is useful to examine hunter-gatherer exchange in other areas. For example, exchange amongst Australian Aborigines is better documented, and the information is used here cautiously as a general informative model.

3.2 Exchange and Trade Defined

The term "exchange" is preferred over "trade" since they are two different methods of acquiring resources. For example, exchange may include delays before obligations are fulfilled; the value of a good may not be based on economics, but on social values, and exchange includes fixed sets of partners (e.g., from father to first son to second son to father's brother's son living elsewhere). Trade does not necessarily involve fixed partners, and the equivalence of value is expected. Trade is not likely to involve recriminations and sanctions, but this can arise in exchange situations when one partner feels neglected by another, or the latter is tardy in reciprocating an exchange.

3.3 Exchange in Hunter-Gatherer Societies

Although ethnohistoric and ethnographic documentation on exchange is lacking for the Nechako Plateau, Post-contact examples are known from the southern Interior of BC and the Columbia Plateau. Forms of exchange were possibly altered and/or adapted

after Contact, when goods made from metal were introduced along with horses. The result was the gradual or rapid abandonment of traditional tools and raw materials (e.g., tool stone, watertight baskets, stone adzes (celts), and animal hides). Hunter-gatherers in Australia and in the Plateau regions of western North America were amongst the last contacted by Europeans, and are thought to share similar forms of exchange.

In Australia, one example of kinship exchange required that a resource or finished product only move in one direction (Fisher 1997). On the Daly River, in the Northern Territory of Australia, the form of exchange is called the "*merbok*". The *merbok* takes place when an item (e.g., Kimberly knife point) is received by one *merbok* partner from another and is kept and used for a while, and then passed on to yet another *merbok* partner. There is no time limit or rules regarding how long an item can be kept, the receiver must determine the time frame and eventually pass the item onto another person. The items of exchange varied from wood, to stone, bone, and even food). Anthropologists considered the *merbok* an influential exchange system, because of the exposure to multiple types of items passed from one individual to another (McCarthy 1939:432). The exchange of different resources and materials allowed the receiver to become familiar with and use materials normally not available without the *merbok.*

On the Columbia Plateau, a similar form of kinship exchange existed amongst the Wenatchee, in which each family had a hereditary trading partner known as a *sćúq*^{w}*i?*, for a male family member in every generation. A man could only exchange with his *sćúq*^{w}*i?* partner, and scheduled his visit during large gatherings where he could personally meet his *sćúq*^{w}*i?* partner (Miller 1998). The *sćúq*^{w}*i?* assured a reliable supply of resources exchanged between partners. A form of exchange similar to the *merbok* or the *sćúq*^{w}*i?*

may be evident in ethnohistorical observations, where in 1806 metal axes forged at Fort Mandan, Missouri, were found in the western Plateau and beyond. These axes were transported in one direction only and likely through a series of exchanges over a period of 14 months, across nearly 1000 miles (DeBoer 2001:216; Ronda 1984:103-104; Wood 1980).

A balanced exchange involves resources with similar values. There are examples of this form of exchange between Interior Columbia Plateau and Plains groups. The Plateau groups carried coastal materials eastward such as dentalium shells, (Barton 1994), haliotis, and olivella, along with Plateau products such as salmon, salmon oil, woven bags, horn bows, wooden bowls, greenstone, pipes, wild hemp, berries, meats, moose skins, spoons made from mountain sheep horn, and basketry (Teit 1900, 1906, 1909). In return, the Plains groups exchanged in a westward direction, bison robes, feather bonnets, catlinite pipes, obsidian, buffalo horn; buffalo bone beads, pemmican, paints, buckskin clothing, and horse equipment (Griswold 1954; Walker 1997). The commodities were considered of equal value because of the distance traveled, but the communication and interaction introduced new materials and techniques for making clothing and tools, to each geographic region. In fact, buffalo hides from the Plains were so plentiful and available through exchange in the Similkameen region of the southern BC that they became more popular than buckskin (Teit 1930).

In Australia and the Interior and Columbia Plateau, men acted as middlemen or carriers of resources in exchange systems (Sharp 1952; Teit 1909; Tindale 1974). For example, a Ngandi man in Australia was a carrier of exchange parcels of unifacially flaked quartzite blades used as spear points or knives (Tindale 1974). The parcels acted

as a passport, allowing the man to cross into foreign territories to exchange and renew or establish kinship relations. Similarly, middlemen in the Columbia Plateau were allowed to traverse through neighbouring territories when transporting materials for exchange, thereby conveying safe passage outside of their traditional territory (Stern 1998). In the Interior Plateau, Shuswap and Chilcotin would not exchange directly with each other. Middlemen would buy products from both groups and exchange them on behalf of each group, making a profit (Teit 1909). Implicitly this suggests that in order to minimize conflict, a type of diplomatic immunity was recognized by all that participated in these systems.

In addition, food surpluses from one area could be included in the exchange network. This allowed the territorial owners of the land on which the resource existed to increase individual or group prestige by controlling access to desirable resources (Jochim 2006). Specific examples of this can be found on both continents, such as the exchange of smoked Shortfin eel (*Anguilla australis*) meat in Australia. Other examples include baked and smoked cakes made from the body fats of the Bogong moth, from the Bogong Mountain region of southern New South Wales and Victoria, and smoked salmon on the west coast of North America (Bennett 1834: I: 272; Builth 2006; Flood 1980:77; McCarthy 1939). The exchange of these food resources was the result of surpluses produced at peak maturity periods for each species, which allowed large numbers of people to meet when water and food was most reliable (Lourandos 1985; McBryde 1987).

Salmon harvesting on the Columbia Plateau is another example of control of resource surpluses. Seasonal harvesting of salmon by groups at owned and protected

locations, and the sharing of human labour (e.g., netting, cleaning, smoking salmon) with outside groups, can be seen as examples of people coming together for both subsistence and economic purposes when salmon surpluses were at their peak (Fladmark 2009; Walker 1998). At this time salmon harvesting locations were also a principle location for Aboriginal people to congregate and exchange. The two most abundant salmon-fishing locations in the Columbia Plateau, Okanagan Falls and Kettle Falls, for example, were recognized as the two predominant exchange locations before and after the introduction of the horse (Teit 1930). In BC, large numbers of Aboriginal people would congregate along the Fraser River from August to September to fish for salmon and exchange other resources (Teit 1906).

3.4 Exchange Routes

Trails across the Nechako Plateau represent routes repeatedly used over space and time by Aboriginal peoples. These trails facilitated movement, transport, and exchange of materials across the landscape from temporary and permanent settlements, and resource locations. The Mackenzie Trail passes through the Punchaw Lake site and through regions with sources of dacite and obsidian, which have been found on archaeological sites across BC (Carlson 1994; Fladmark 2009). The role of these trails in the transport, distribution and/or exchange of dacite resources in this region remains unknown, however, it seems logical to assume that many of the igneous materials were transported in this manner. The abundance of dacite on archaeological sites throughout the region suggests that it was likely as major an item for transport and exchange, as was obsidian.

Galm (1994) and Sappington (1985) determined that obsidian was exchanged throughout the Interior Plateau and that known trails were used for this purpose. Obsidian was transported along the west coast and interior landscapes from Alaska, through BC, and south to California (Carlson 1994; Wright and Carlson 1987). The use of trails to transport and exchange resources is also supported at Marmes Rock Shelter and other sites on the Columbia Plateau, where remains of hundreds of coastal olivella shells and obsidian fragments dating back as far as 7,000 (uncalibrated) years ago have been recovered (Galm 1994; Walker 1997). It is also possible that aboriginal people followed a trail not known today, which could have passed through the Nechako Plateau and close to known sources of tool stone (Fladmark 2009).

In post-contact BC, trails were altered to conform to new methods of transporting goods with horses. Teit (1930) notes, "following the introduction of the horse, exchange conditions changed rather suddenly, and old exchange routes became of minor importance." The new trails followed across rolling, lightly forested grassy plateaus and open valleys, in almost straight lines from one geographic region to another (Fladmark 2009). Interior trails such as the "Grease Trail" may have been created for overland travel and exchange purposes due to the introduction of the horse. Trails were used on a seasonal basis to transport oolichan fish oil between coastal and central interior hunter-gatherers, along routes from Bella Coola to the Coast Mountains and along the Blackwater Valley to the Fraser River near Quesnel (Brown 2002:42). These trails are located in proximity to the Punchaw Lake Village site (See Figures 4) and the surrounding region (See Figure 5). The juncture of the Alexander Mackenzie Heritage Trail and the Punchaw Lake-Fraser River Trail is located at the southwest corner of

Punchaw Lake. These two trails predate 1846 when the Hudson Bay Company began to map and record routes across the landscape, indicating they were in use before European contact. Historical evidence suggests that what is now known as the Mackenzie Trail and others were used in Pre-contact periods before Alexander Mackenzie passed through in 1793 (Mackenzie 2001: 323). A common method of transporting goods by foot is tumpline baskets (Teit 1928, 1997) used throughout the Americas, from Alaska to the Straits of Magellan (Mason 1896). Depending on load weight, travel experience, including distances and seasons of the year to travel, it could take a day to several days of crossing river valleys and mountain passes to reach a destination. Ethnographic observations suggest values for individual capacities for trade goods using this method. One can also interpolate similar values for lithic raw materials.

Stern (1998:641) mentions that "baskets filled with 'salmon pemmican' or 'sugar salmon' would weigh upwards of 100 pounds a piece," and were likely transported by foot on known overland exchange routes. The number of days it took to transport a basket of this much weight is unknown, as the persons transporting a heavy burden would need to pace themselves as they crossed over varying elevations and take extended rests. Malville (2001) conducted a study of on-foot transportation by families in the eastern hills of Nepal, which found that the self-organized and self-paced Nepali porters progressed slowly while toting heavy loads weighing 73 kg. Crossing deep valleys and high ridges and using trails that varied in width and surface, they moved at a rate of about 8 to 11 km per day, covering a total distance of 95 km over 9 to 12 days (Malville 2001). The return trip would take four days at an approximate rate of 24 km per day (Malville 2001). The landscape of the Nechako Plateau (1200 to 1500 m above seas level (a.s.l.)

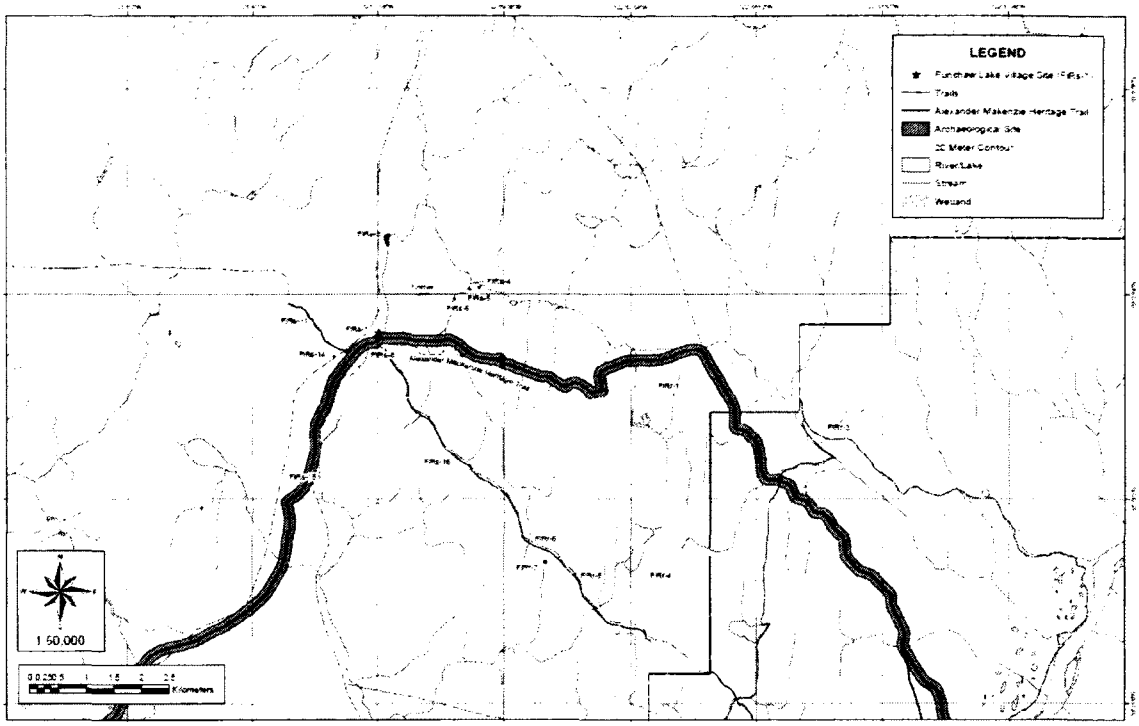

Figure 4: Historic trails in proximity to the Punchaw Lake Village site.

See Figure 6), in proximity to the Punchaw Lake Village is less challenging physiographically than the eastern hills of Nepal, where the elevations are 1200 to 3500 m a.s.l. (Malville 2001). The less extreme differences in topography would allow for easier and faster transportation of resources along land routes if the weight of tumpline baskets was not too burdensome for the carrier.

Mackenzie describes the load weight carried on their backs and distances traveled in one day while traveling through an area inhabited by the Nascud Denee. He states: "We carried on our backs four bags and a half of pemmican, weighing from eighty-five to ninety pounds each. The Indians had forty-five pounds weight of pemmican to carry. The distance of this day's journey was about twelve geographical miles." (Mackenzie 2001: 323). These historical descriptions confirm that heavy loads were transported along

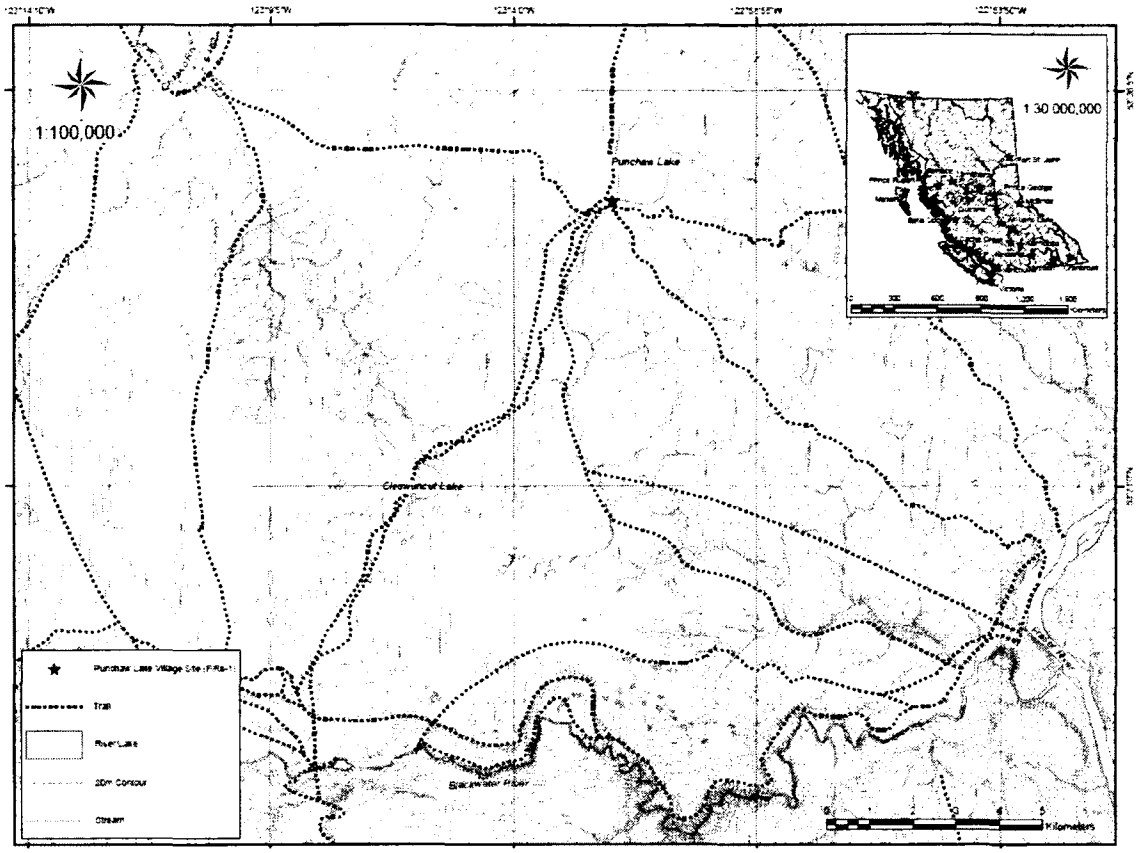

Figure 5: Historic Trails surrounding Punchaw Lake.

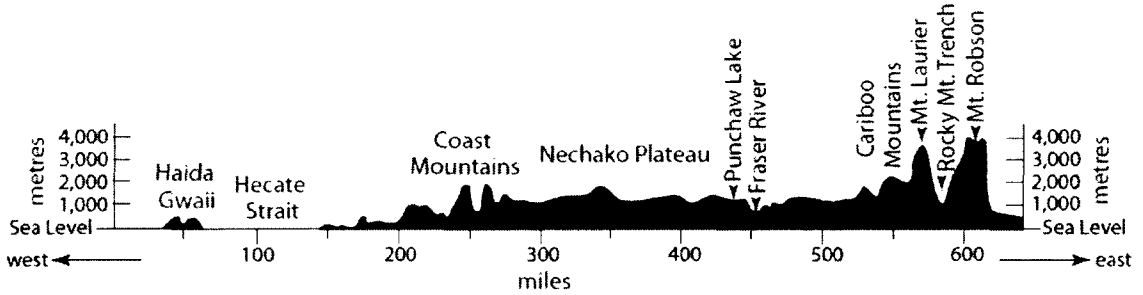

Figure 6: Profile of Northern Interior Plateau. (Adapted from Donahue 1978, Figure 1).

trails over the landscape and that distances traveled in a day varied with topography and load.

In one other example, Allison (1892:306) describes how Aboriginal people were employed to pack provisions on their backs. "Their packs were suspended by means of a band or strap passed over their foreheads. I have known some of them to pack three sacks of flour (150 lbs.) on their back, while travelling on snow-shoes for a distance of 65 mile over rough mountainous road with a depth of 25 feet of snow on the summit of Hope Mountain, over which the trail ran."

Hayden (1989) estimated that a family is able to carry no more than 1-2 kg of stone; however, Malville is convinced that historically people carried much heavier loads. Malville (personal communication, 2006) suggests more than 10 to 20 kg could be carried if they used the simple load-carrying technologies that Mason (1889, 1896) documented for various hunter-gatherer groups in the 19th Century. Ethnohistorically, Teit (1928:250) claimed "when trade was conducted either on foot or by canoe, the articles exchanged had been of necessity light and of high value, while trading parties were small and infrequent." The average load in relation to body weight cannot be determined for past cultures. However, Malville (2001) did find the average load in relation to body weight for adult Nepali males to be 123 % for domestic loads, 147 percent for commercial loads, and 157 % for self-employed traders; young porters (10-14 years) carried on average loads of about 35 kg, equivalent to more than 100 % of their own body mass. Ethnohistoric observations and current estimates for average load in relation to body weight as presented by Malville (2001) appears to contradict both

Hayden (1989) and Teit (1928) in their estimates of the maximum weight an individual is capable of carrying.

There is no direct evidence to support the use of watercraft on lake and river routes in proximity to the Punchaw Lake Village site. However, the ethnohistorical record suggests pole rafts; shallow canoe-shaped vessels made from rushes and bundles of mats; bark canoes; and dugout canoes may have increased in use especially after the introduction of metal woodworking tools (Teit 1928, 1930). It would seem quite plausible that use of watercraft preceded Contact and that such vessels could have been used in aid of transporting materials for exchange, along the lakes and rivers.

Currents, obstructions to navigation, types of watercraft, changing hydrographic conditions, and shifting sinuous river courses (Drennan 1984) could affect the rate of transport. Adams (1978) noted that a hand propelled dugout in and around Petén, Guatemala would travel approximately 20 km per day upstream and 40 km per day downstream on a slow moving river.

Aboriginal people utilized the landscape by establishing trails for the procurement and transport of resources (e.g., dacite) and other cultural material across the Nechako Plateau. Trails would have facilitated exchanges amongst Aboriginal people living within and outside this region. However, the lack of documented forms of exchange in this region makes it difficult to quantify the level of communication and co-operation necessary to transport or receive resources throughout the region.

Australian Aboriginal forms of exchange are similar to those from the southern Interior and Columbia Plateau, and suggest that these forms of exchange are common in hunter gatherer societies. It is likely that trails were an important means of

communication and exchange in many parts of the world. The location of Punchaw Lake Village site next to major trails suggests artifacts made from dacite and/or trachydacite were potentially transported from other locations, and that the village may have been an exchange centre at various times. The presence of multiple types of rock should not be surprising, however, the rest of this thesis centers on testing that notion.

CHAPTER 4: TOOL STONE PROVENANCE STUDIES IN BRITISH COLUMBIA

The artifact assemblage at the Punchaw Lake Village site and at archaeological sites across BC consists of a variety of tool stones originating from numerous provenances, many of which remain unidentified or unknown. Archaeologists and geologists have endeavoured to use various techniques to classify rock types based on petrographic observations and on element concentrations. These rock types often display similar external macroscopic characteristics, making visual classification difficult. In British Columbia major and trace element analysis has been used to classify rock types and to identify specific provenances. Of all the rock types, obsidian has received the greatest amount of attention in the archaeological literature, although greater efforts are now being placed on other toolstone materials.

4.1 Obsidian

Obsidian, or volcanic glass, is an igneous rock composed primarily of silica, which forms as lava cools quickly. It flakes relatively easily and produces sharp cutting edge, it is brittle, and easy to recognize visually. Because of its chemical homogeneity and isolation of known provenances, obsidian has been a useful tool stone for provenance research and exchange studies in BC and elsewhere (Carlson 1994; Galm 1994).

Wilmeth (1973:28) examined trace elements composition via instrumental neutron activation analysis (INAA) to determine the provenance of obsidian found at several sites near Anahim Lake, BC. This initial study (Evans and Wilmeth 1971) was

based on 23 obsidian samples from four separate geographic areas; the study identified two sources of obsidian in the Anahim region, Dean River and Anahim Peak. The results were based on a comparison of major and trace element concentrations (e.g., Fe, Ta, Sc, Ce, Rb, Yb, and Th). The pilot study was later followed by a similar examination of a larger collection of obsidian samples from 21 archaeological sites and nearby provenances, with the help of archaeology colleagues and the Geological Survey of Canada (Wilmeth 1973). In the second study Wilmeth (1973) used both INAA and X-ray Fluorescence (XRF) to chemically characterize obsidian samples and assigned them to 12 formal groups. Analyses were based on trace element concentrations (e.g., Fe, Ce, Yb, Hf, Sc, Rb, and Ta). Wilmeth (1973) pinpointed geographic regions from which the obsidian originated. For example, samples from Group 1, the most widely distributed obsidian, originated in the Rainbow Mountains and Dean River areas. Not all obsidian samples could be sourced to a region, as some samples originated from unknown provenances.

Nelson and Will (1976) conducted further field studies in 1973 to test obsidian flows for chemical homogeneity in the Anahim area using energy-dispersive XRF (ED-XRF). Some 18 randomly selected obsidian pebbles were recovered from the Dean River (also known as Obsidian Creek), and eight flakes were taken from an archaeological site, including a partial point made from obsidian. The goal of this study was simply to characterize obsidian flows (Nelson et al. 1975: 88). The geochemical analysis was based on the examination of major and trace element concentrations (e.g., K, Ca, Ti, Mn, Fe, Zn, Ga, Pb, Rb, Sr, Y, Nb, and Zr) (Nelson et al. 1975: Table 2). Specific elements such as Rb, Sr, Y, Zr, and Nb had intensities particularly useful to distinguish differences

between each sample tested (Nelson et al. 1975:93). There was no indication of element signatures for different samples in this study. The Nelson and Will (1976) study determined that the obsidian samples had a unique, easily recognizable fingerprint and the obsidian flow was homogenous. Obsidian samples collected by Wilmeth were also tested and found to have similar element concentrations to samples analyzed by Nelson and Will (1976).

Fladmark (1985) carried out field research on obsidian flows at the Mount Edziza volcanic complex in northwestern BC, while Godfrey-Smith (1985) used Energy-Dispersive X-ray Fluorescence (ED-XRF) to analyze these flows. Godfrey-Smith (1985) attempted to: obtain chemical composition of obsidian samples from ten obsidian flows, to determine variation; and to use the data to better understand obsidian use in antiquity. Analysis of specific major, minor, and trace element concentrations was conducted to determine chemical relationships amongst the ten obsidian flows. For major elements (Si, Ti, Al, Fe, Mn, Mg, Ca, Na, K, P), minor elements (Ba, Co, Cr, Cu, Mn, Mo, Ni, Pb, Rb, Sr, Va, Y, Zn, Zr, Nb), and rare earth elements (Ce, La, Nd). Chemical compositions from the ten flows had unusually high concentrations of Fe content and wide concentration ranges for Ti, Al, Mn, and several of the trace elements (Godfrey-Smith 1985:114). In addition, all ten flows had a high enrichment of trace elements Rb, Sr, Y, Zr, Nb, rare earth elements Ce, Nd, La, and low content of Ba and Sr. The results indicate the ten obsidian flows could be grouped into three specific classifications of peralkaline volcanic rocks. Godfrey-Smith gives the specific chemical signature of the obsidian flows (1985: Table 7). The chemical composition of 174 obsidian samples and 169 obsidian artifacts from 3 archaeological sites identified five flows as pantelleritic rock,

three flows were mildly peralkaline and classified as comendites, and two flows were interpreted as sub-alkaline (Godfrey-Smith 1985:114). The interpretation is that Aboriginal people were selective in their choices of obsidian to procure for every day use, and in some cases, selected material on a seasonal basis.

James et al. (1996) used X-ray Fluorescence (XRF) to establish an obsidian database inventory using samples from 11 sources within different regions of western North America, also associated with archaeological sites through previous research. The analyses focused primarily on trace element compositions, as they have proven most useful to analyze obsidian (e.g., Rb, Sr, Y, Zr, K, Nb, Fe, and Zn). As a result, James et al. (1996) were able to confirm known provenances of obsidian and added new ones the library, increasing the total number (e.g., 32) of different obsidian types in British Columbia.

In 1974, a Canada Council grant was secured to address the directionality of prehistoric obsidian exchange in British Columbia through the application of energy dispersive x-ray fluorescence (ED-XRF) (Carlson 1994). The project had two goals: (1) determination of the geographic distribution of obsidian in British Columbia from given sources; and (2) determination of the time occurrence in the archaeological record, of obsidian from the various sources (Carlson 1994: 310). A total of 1,302 obsidian artifactual samples from 121 archaeological sites in BC and 59 sites in adjacent areas were characterized. Twenty different sources were referenced for this study, and up to thirty distinctive fingerprints were derived from artifactual samples, but not all could be matched to known obsidian sources (Carlson 1994).

As part of this study 109 obsidian samples from the Punchaw Lake site were analyzed with ED-XRF. The results indicate that samples originate from four different provenances (e.g., Anahim, Ilgachuz, Mackenzie, and Edziza), suggesting obsidian was transported and exchanged from regions outside the Nechako Plateau (Carlson 1994: 321, Table 10).

Carlson's study (1994) revealed that obsidian has been the only indicator of exchange across the entire span of 9,500 years of Aboriginal culture in BC. Obsidian exchange is thought to have increased gradually between 9,500 and 6,000 BP followed by a rapid expansion between 6,000 and 4,000 BP, and leveling off in later periods (Carlson 1994). This volcanic glass and other commodities were consistently exchanged through time by Aboriginal communities along the coast and interior of BC, and adjacent areas.

4.2 Dacite and Trachydacite

Richards (1988) carried out the earliest attempt to characterize toolstone other than obsidian in BC to understand the relation between tool-use behaviour and microwear patterns on Cache Creek basalt stone tools. As part of this study, Richards examined petrographic thin sections from a sample of 17 basalt cobbles to identify their geologic provenances. In addition, he attempted to identify specific lithologic characteristics based on microwear properties of vitreous and non-vitreous basalt internal compositions (e.g., fine grained, homogeneous, and heterogeneous). The internal description of basalt cobbles indicated a fine, medium, and coarse-grained material with black to dark grey colours, and varying microscopic internal textures for each sample (Richards 1988: Table

2). In a later re-examination of these samples, Bakewell and Irving (1994) and Bakewell (2000) determined the rock types (e.g., Richards' basalt samples) had been misclassified.

In a petrological and geochemical (ICP-ES) analyses of archaeological samples, Bakewell and Irving (1994) reclassified tool stone samples from the Interior Plateau as rhyolite due to high silica content (69.1%) and not basalt as previously described by Richards (1988) and Magne (1979). The re-classification was based on the chemical classification of volcanic rocks recommended by the International Union of Geological Sciences (I.U.G.S.) Subcommission on the Systematics of Igneous Rock (Le Maitre 1989, See Figure 7). The classification scheme plots the variation of total alkalis (Na_2O + K_2O) versus SiO_2 in weight percent (wt. %). Material previously described as basalt by Richards (1988) was reclassified as trachydacite and/or rhyolite, as the silica contents range was close to that of dacite but with a higher alkali content.

Commisso (1999) set out to determine if X-ray Florescence Spectrometry (XRF) could be successfully used to chemically characterize and distinguish a known source of lithic material other than obsidian (Commisso 1999:1). From the Arrowstone Hills of BC, ten cobbles were collected from different provenances, with additional archaeological samples collected from disturbed areas of a prehistoric quarry. The intent of the study was to obtain chemical data on minor, trace, and major elements to classify each of the samples. The major elements examined were Al_2O_3, Fe_2O_3, K_2O, MgO, Na_2O, P_2O_5, SiO_2, CaO, Mn_3O_4, TiO_2, minor and trace elements are Ba, Rb, Sr, Zr, Y, Zn, V, Co, Cu, Cr, and Ni. Based on SiO_2 (wt %) (Approximately 67-71%) nine of ten samples were classified as a rhyolite and one sample as dacite. Commisso (1999) compared samples from the Arrowstone Hills, Trachyte Hills and Cache Creek to determine if they could be

distinguished. The Trachyte and Arrowstone Hills samples were impossible to distinguish from each other, despite a separation of 30 km. However, Cache Creek and Arrowstone Hills samples exhibited distinct differences when trace elements were compared (e.g., Za compared to concentrations of Ba/Sr, and Zr compared to concentrations of Sr/Y). Despite the limited range of elements used, XRF was effective for geochemical characterization of each sample in order to classify the rock type and determine what element concentrations were similar or different between samples.

Mallory-Greenough et al. (2002) and Greenough et al. (2004) used a combination of analytical techniques; petrography, ICP-MS and ES and electron microprobe for major and trace-element analysis to determine the overall chemical composition of samples tested. Major elements selected to determine the chemical composition were SiO_2, TiO_2, Al_2O_3, Fe_2O_3, MnO, MgO, CaO, Na_2O, K_2O, P_2O_3, and trace elements Rb, Cs, Sr, Ba, Zr, Hf, Ta, Nb, Th, U, La, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu, Y, Ga, Sc, V, Ni, Tl, Zn, Cu. The researchers identified up to five secondary provenances of dacite in the southern Interior Plateau of BC, where samples were collected in areas of glacial drift or where outwash had occurred. Trace elements Rb, Sr, Ba, Y, Nb, U, Th, V, and TiO_2 were used to determine that each artifact/bedrock sources were distinct from each other (Mallory-Greenough et al. 2002: Figure 9). In addition, their study showed that raw material used in stone tool manufacture was predominantly local in origin (Mallory-Greenough and Greenough 2004). The researchers point out that although dacite suitable for tool manufacture exists in the BC interior, not all dacite sources are suitable for tool manufacture (Mallory-Greenough et al. 2002; Greenough et al. 2000).

Smith (2004) attempted to classify 13 igneous artifacts from a set of 33 igneous and non-igneous samples. In addition, to explain possible behavioural relationships between raw material and selected stone tool types, and determine whether these relationships change through time. All samples originated from the Richardson Ranch site on Haida Gwaii and represented the most frequently occurring materials found in the artifact assemblage.

Smith (2004) used a combination of analytical techniques to perform her analysis of the artifacts. These included a macroscopic visual assessment of the samples selected, Electron Microprobe analysis (EMPA) to determine major element compositions, and Laser Ablation-Inductively Coupled Plasma-Mass Spectrometry (LA-ICP-MS) to determine Trace and rare earth elements (REE). Samples crushed into a fine powder and transformed into homogeneous glass beads intended for reuse when using an EMPA and/or LA-ICP-MS. The major elements selected for Richardson samples were Na, Mg, Al, Si, K, Ca, Ti, Mn, Fe, and the trace and rare earth elements were Sc, Ti, V, Cr, Ni, Sr, Y, Zr, Nb, Ba, La, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu, Hf, Ta, Th, and U (Smith 2004: Table 4.3 and 4.4). Smith (2004:61-64) separated igneous versus non-igneous samples based on a plot of log using elements SiO_2/Al_2O_3 versus log (CaO + Na_2O)/K2O. The study separated and classified 13 samples as igneous rhyolite and dacite, 18 samples were non-igneous, two samples are regarded as transitional non-igneous rocks. The chemical data was used to determine the types of raw material used for stone tools recovered from the dated stratigraphy of the Richardson Ranch site.

4.3 Summary

This chapter is a summary of attempts in BC to develop an analytical methodology that can be replicated by other researchers working on sourcing artifact assemblages to provenances. Element concentrations have proven useful in these endeavours to identify unique provenances and to classify rock types in artifact assemblages. Studies focusing on element concentrations suggest that a more regional or local database, rather than a Provincial database, is more effective to understanding the relationship between artifacts and provenances. Such studies can identify unique element characteristics of tool stone and pinpoint where the material may have originated. In the case of Punchaw Lake Village site, analysis of element concentrations plays a key role in exploring the physical variation in each sample.

CHAPTER 5: METHODS

5.1 Introduction

To test the hypothesis that one (non-obsidian) igneous provenance is reflected in the Punchaw assemblage, several techniques were employed to explore the physical make up of, and possible variation within, the overall collection. Initial samples were sorted using macroscopic visual analysis (MVA). From each group one sub sample was subjected to a petrographic analysis, while a second sub-sample was analyzed using Inductively Coupled Plasma Mass Spectrometry (ICP-MS) and Emission Spectrometry (ES). Results from the latter are interpreted via the use of quantitative analysis described below. The use of multiple analytical techniques allows for greater robusticity in the interpretations.

5.2 Sample Collection and Macroscopic Visual Analysis

The analysis focuses on igneous compositional variation (trachydacite or dacite) despite the strong representation of obsidian, chert, and quartzite in the artifact assemblage. Obsidian was excluded here as Carlson (1994) has conducted previous work on sourcing this material at the site. In keeping with work done in adjacent areas (Bakewell 2000; Bakewell and Irving 1994; Heffner 2010; Magne 1979; Mallory-Greenough et al. 2002; Greenough et al. 2004; Richards 1988; Smith 2004), the focus here is on the non-obsidian igneous component. These tend to be the dominant raw materials at many sites in the central southern interior of the province. Other materials

such as chert and quartzite were excluded in this study, but they may be examined at a later date..

Approximately 6,000 igneous flakes were recovered at this site, and all were examined via preliminary MVA to classify them into groups. This step was taken to select a smaller representative sample that could be subjected to petrographic and geochemical analyses. It would be financially prohibitive to submit a sample of 6,000 specimens for such analyses, and yet a completely random sample might miss the variation represented in the overall flake collection.

The MVA was implemented to create a representative sample through visual observation of key characteristics. Macroscopic visual analysis, also known as individual attribute analysis (IAA), has been previously used in this manner to classify flaked stone into groupings based on colour, crystalline inclusion, surface, texture, patterning, fractures, and streak test (Janusas 1984; Milne et al. 2009; Smith 2004).

In the present study, surface texture was determined by manually rubbing the surface of each flake to determine whether it bears a smooth or rough surface, and color of the flake was recorded. Internal texture and colour were observed after removing a fresh surface flake with a stainless steel punch to expose the internal matrix. Some flakes had developed a weathered surface resulting in a change to the external surface colour. The classification was aided by the use of "one control sample flake" comparing the interior of the control sample with the interior of flakes selected for further analyses using a stereomicroscope at 10x magnification. The purpose of this was to distinguish internal textural and colour differences.

5.3 Petrographic Analysis

Payne (2006) has been the senior petrographic examiner for Vancouver Petrographics for 39 years and conducted a petrographic analysis on a sub-sample derived in the MVA, to examine internal texture, crystal size, and mineralogy. The purpose of the petrographic analysis was two fold: First, the analysis determined if a flake sample from each of the MVA groups exhibit distinct characteristics, thereby providing support to the macroscopic grouping. Second, petrographic observations could be used to assess general variation in raw material to test whether or not all samples originate from a single source.

Microscopic petrographic analysis of a rock sample helps to identify its mineral phases, their abundances, textures, and age relationships, which aid in determining the geological provenance and history of the rock (Le Maitre 2002). For microscopic analysis, a rock sample is cut, rough-polished, and mounted on a glass plate, and then is ground to a standard thickness of 0.03 mm and covered with a thin protective glass plate. At this thickness, many minerals are translucent, and their distinctive optical properties in transmitted plane and polarized incident light make their identification relatively simple (Gribble and Hall 1985:28; Mackenzie and Adams 1994:220). Opaque minerals require a polished thin section, for which the ground sample is polished and not covered by the protective glass plate, and is examined in reflected light. Minerals finer than about 0.05 mm commonly are too fine for positive optical determination, and other methods such as X-ray diffraction and scanning electron microprobe analysis are required for positive determination of the mineral(s) (John Payne, personal communication 2012). In previous work on sourcing tool stone materials (Greenough et al. 2004; Janusas 1984; Mallory-

Greenough et al. 2002; Milne 2009; Richards 1988) researchers have used similar microscopic petrographic analyses.

5.4 Geochemical Analysis

The analysis was carried out at ACME Laboratories in Vancouver, BC, which is ISO9001 certified and follows a rigorous control program that includes the insertion of a variety of blanks, duplicates, and certified references materials as well as multiple levels of data validation (Bill MacFarlane, ACME Labs, Personal Communication 2011). Data are discussed in Appendix VII. Eighteen flakes were tested for major, trace, and rare earth elements using Inductively Coupled Plasma-Mass Spectrometry (ICP-MS) and Emission Spectrometry (ES) (See Appendix III). Sample powders of 0.2 g were weighed into graphite crucibles, mixed with 1.5 g of $LibO_2/Li_2B_4O_7$, and fused at 980°C. Samples were dissolved in 0.5 percent HNO_3 and then aspirated into a Spectro Ciros Vision ICP-ES. Major element oxides (expressed as weight percent [wt %]) SiO_2, Al_2O_3, Fe_2O_3, CaO, MgO, Na_2O, K_2O, MnO, TiO_2, and P_2O_5 were determined by ICP-ES. Trace elements concentrations, (expressed in parts per million [ppm]) Cr, Ba, Nb, Ni, Sr, Sc, Y, and Zr were also determined by ICP-ES.

Trace and rare earth element concentrations Ba, Co, Cs, Ga, Hf, Nb, Rb, Sn, Sr, Ta, Th, Tl, U, V, W,Y, Zr, La, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, and Lu were identified using a Perkin-Elmer 6000/9000 ICP-MS after sample dissolution similar to preparation for the ICP-ES. A second sample split of 0.5 g was digested in aqua regia and analyzed by ICP-MS to identify Au, Ag, As, Bi, Cd, Cu, Hg, Mo, Pb, Sb, Se, Tl, and

Zn. It should be noted that Au, Ag, Bi, Cd, Sb, Se, Tl, Hg, and Ni by ICP-ES were not used for element concentration comparisons of each sample.

Both inductively coupled plasma (ICP) emission spectrometry and ICP mass spectrometry, an extension of emission spectrometry, are relatively new techniques for geochemical analysis (Rollinson 1993:13). ICP emission spectrometry is a solution technique and standard silicate dissolution methods are employed. A sample solution is passed as an aerosol from a nebulizer into argon plasma. The inductively coupled plasma is a stream of argon atoms, heated by the inductive heating of a radio-frequency coil and ignited by a high frequency Tesla spark (Rollinson 1993). The sample dissociates in the argon plasma and a large number of atomic and ionic spectral lines are excited. A range of photomultipliers detects the spectral lines, they are compared with calibration lines, and their intensities are converted into concentrations (Rollinson 1993)

In principle, ICP-ES is capable of measuring most elements in a periodic table with low detection limits and good precision (Rollinson 1993:13). Elements are measured simultaneously and a complete analysis can be made in the space of two minutes, making it an extremely rapid analytical method. Due to its low detection limits, good accuracy, and precision ICP mass spectrometry is the generally accepted tool for trace element and isotopic analysis (Rollinson 1993:15). A wide range of trace elements can be analyzed, in a single solution, using a small sample (Rollinson 1993).

5.4.1 Issues of Weathering

Given the small size of the flakes, and thin weathering surfaces (approximately 1 micron), samples were thoroughly washed in distilled water prior to chemical analysis.

Although surface weathering can impact Mg, K, Na, Ca, and to some degree Si concentrations (Rollinson 1993), multiple analyses of different parts of two artifacts, which had varying quantities of weathering-exposed surfaces removed, returned bulk-rock chemical analyses that are within analytical error of one another (See Appendix V). Following these results, the assumption is that weathering does not have a large impact on the overall chemical analyses. Other researchers have also concluded that there is no evidence to support any major impact of weathering on such samples (Hunt 1991; Smith 2004; Nelson et al. 1975).

5.5 Test for Internal Homogeneity

Two flakes were selected to test for internal homogeneity. Different rates of cooling within a lava flow can cause certain elements to become more concentrated in specific areas and depleted in other areas (Rollinson 1993). Differential cooling can potentially result in one provenance displaying several different chemical fingerprints, which would make testing the null hypothesis in this research difficult, if not impossible. To ensure that this is not a confounding factor in the present study, the internal homogeneity of two flakes were tested. Dr. John Greenough provided access to facilities and equipment at the University of BC, Okanagan campus, and assisted with the interpretation of the ICP-MS and -ES chemical data using Multidimensional Scaling (MDS).

To prepare the flakes, weathered surfaces were removed with a diamond lap. Each flake was subsequently broken into smaller pieces using a stainless steel rock hammer. Flake No.18 was reduced into two sections and No.17 was reduced to three (i.e., two end-

sections and a mid-section). Each section was separately placed into a powdering bowl (mill) made of alumina (corundum). The powder from each flake was crushed and pulverized to -150 mesh and kept in sterile 10 gram (g) bottles. After each flake was ground into a powder and removed, the bowl was washed with hot tap water, rinsed with distilled water, and dried with a sterile towel.

Powders came from different locations on each sample. Flake No.17 was broken into three pieces and crushed as noted above. One end piece provided six 10 g bottles of crushed powder (e.g., Geo 1-6); a middle piece provided one 10 g bottle (Geo 7); and another end piece provided two 10 g bottles (Geo 10-11). Flake No.18 was broken into two half pieces, with one piece producing two 10 g bottles (e.g., Geo 8-9) and the other half producing two 10 g bottles (e.g., Geo 12-13) (see Appendix V)

Each 10 g bottle was tested using ICP-MS and -ES to determine if any of the powders exhibited unique chemical characteristics. Multiple analyses demonstrate that each section has a composition within analytical error of each powder tested. Precision and accuracy of the samples were determined using whole rock and aqua regia digestion charts provided by ACME Laboratories (See Appendix IV and V). Variation on the composition of three powders from different parts of this artifact is essentially the same as precision estimates. So for flake No.17, precision and accuracy were generally better than 1% for the major element oxides. Most trace elements have precision and accuracy better than 5%, except Ta, Zn, Cu (<10%); Ni (15%); Cr, Pb, and W (30-45%). See Appendix V for precision and elements standards tables.

5.6 Statistical Analysis of Element Concentrations

Multidimensional Scaling (MDS) and Cluster Analysis (CA) are exploratory and descriptive quantitative methods used to determine if meaningful clusters can be produced from element concentrations resulting from the geochemical analyses of selected samples. These two quantitative methods were used to determine how similarities of each flake are represented within the sets of clusters formed as each method is capable of producing different results. John Greenough (UBC-Okanagan) provided assistance in the MDS analysis and Ian Berkowitz (SFU-Burnaby) assisted with the CA.

5.6.1 Multidimensional Scaling

A comparison of elements within each flake was completed using MDS, using SYSTAT software (Wilkinson et al. 1992). MDS is a quantitative method that creates a visual representation of patterns in data: objects are grouped on a two-dimensional map, and similarities are indicated through their proximity to one another. MDS reveals natural patterns within the data set to show the relationships between objects and/or variables (data) plotted on a map (Borg and Groenen 1997). These maps are created using Pearson correlation coefficients as a measure of distance between objects. Objects with similarities will appear closer to each other, while dissimilar objects will show increasing distance between each other. In this case, flakes that are similar in element concentrations will plot near or on top of each other, while dissimilar flakes will plot further apart, or as outliers from groups. Flakes that plot away from any groups are defined as a single atypical object disconnected from other data (Kaufman and Rousseeuw 1990: 162).

The matrix of sample versus sample correlation coefficients was prepared by using all data for each sample. In order to ensure that no one element impacted the calculation of the correlation coefficient more than another, all elemental data were standardized (zero mean, unit variance).

5.6.2 Cluster Analysis

Cluster analysis (CA) is an exploratory data analysis tool and consists of a number of techniques that classify by assigning observations to groups, so that each group is more-or-less homogenous and distinct from other groups (Davis 1986). The goal is to sort objects into groups so that the degree of association between two objects is maximal if they belong to the same group and minimal otherwise (Lewicki and Hill 2006). Therefore, CA places objects that share similar values into homogenous groups that share similar values, so that the relationship between sample groups can be observed. These homogenous groups are used to create a dendrogram, which is arranged so that similar objects are placed close to each other; therefore, the longer the horizontal branch, the more dissimilar the pair of objects. The procedure begins by joining the two closest objects as a cluster and continues joining objects until all are combined into one cluster (Ian Berkovitz, personal communication 2009).

Hierarchical clustering, referred to as *agglomerative clustering*, is a combination process that begins with each point (row) as its own cluster. The clustering process calculates the distance between each cluster and combines clusters closest to each other until all points are joined. This method of clustering is useful for smaller data sets (JMP 2008:381, 383).

Ward's method was chosen as the type of CA best suited for this analysis, because it is a unique inter-cluster distance measure that uses an analysis of variance (ANOVA) approach to evaluate the distances between clusters. In short, this method attempts to minimize the ANOVA sum of squares (SS) of any two (hypothetical) clusters that can be formed at each step (Lewicki and Hill 2006). In addition, Ward's method tends to join clusters with a small number of observations and is strongly biased toward producing clusters with roughly the same number of observations (JMP 2002:391).

The 18 samples were compared using 15 variables determined by multivariate analysis, in which a limited number of sample observations should equal the total number of variables -1, or less. The CA was performed using JMP software version 7.0 hierarchical clustering and Ward's method to locate clusters. Before the CA was performed, each of the values was standardized to ensure that all chemical elements selected in Tables 4 and 5 were on the same scale. The variables were standardized (zero mean, unit variance) by calculating their z-scores $(x_i - \bar{x})/ s_x$. The standardization avoids variables with large values from contributing more to the distance measure than variables with small values.

Trace and rare earth elements (REE) (e.g., Sc, Y, Th, U, Pb, Zr, Hf, Ti, Nb, Ta, La, Ce, Pr, Nd, Pm, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, and Lu) are identified as high-field-strength elements (HFSE) (Rollinson 1993:120) are immobile and therefore used in this study. Researchers have used similar elements for rock classification and provenance studies discussed in Chapter 4. Elements selected for CA were Rb, Y, Hf, Zr, Nb, Th, Ta, Ce, Nd, Sm, Eu, Tm, Yb, Lu, and Er.

CHAPTER 6:RESULTS AND DISCUSSION

6.1 Introduction

A number of analytical methods are used to determine if one volcanic rock type is represented in the Punchaw Lake Village site artifact assemblage. The following sections describe the results and interpretations of the: macroscopic visual assessment (MVA); petrographic (microscopic) analysis; Inductively Coupled Plasma Mass Spectrometry (ICP-MS), and Emission Spectrometry (ES) provided major, trace, and rare earth element concentrations to examine sample variation, rock classification and internal homogeneity of selected samples.

6.2 Macroscopic Visual Analysis

To create a representative sample from the flake collection the first step involved examination of physical attributes based on hand-eye observations. A total of four physical attributes were considered. The first attribute was surface colour (e.g., black, and in some cases, grey), which was only observed and not identified with a Munsell colour chart. The second attribute was surface texture, which ranged from smooth surface to coarse-grained. The third attribute was comparing the external and internal colour and texture, which was examined after a fresh surface flake was removed from each sample. Using a stereo-microscope a fourth attribute was added, crystal grain size where observations were possible. From the assemblage of 6,000 flakes, 22 were selected to represent six visually distinct groups based on these four attributes, with two flakes added later in the study (See Table 1).

Table 1: Flakes and Method Used.

Flake No.	Artifact No.	MVA and analytical technique used for each artifact
1	F0146	Macroscopic visual analysis, ICP-MS and –ES
2	F0221	Macroscopic visual analysis, ICP-MS and –ES
3	F0279	Macroscopic visual analysis, ICP-MS and –ES
4	F0331	Macroscopic visual analysis, ICP-MS and –ES
5	F0514	Macroscopic visual analysis, ICP-MS and –ES
6	F0714	Macroscopic visual analysis, ICP-MS and –ES
7	F1090	Macroscopic visual analysis, ICP-MS and –ES
8	F1883	Macroscopic visual analysis, ICP-MS and –ES
9	F2116	Macroscopic visual analysis, ICP-MS and –ES
10	F2642	Macroscopic visual analysis, ICP-MS and –ES
11	F2665	Macroscopic visual analysis, ICP-MS and –ES
12	F2753	Macroscopic visual analysis, ICP-MS and –ES
13	F2758	Macroscopic visual analysis, ICP-MS and –ES
14	F2777	Macroscopic visual analysis, ICP-MS and –ES
15	F2961	Macroscopic visual analysis, ICP-MS and –ES
16	F3124	Macroscopic visual analysis, ICP-MS and –ES
17	F2761	Split into three pieces to analyze internal chemical variation, ICP-MS and –ES
18	F0272	Split into two pieces to analyze internal chemical variation, ICP-MS and –ES
19	F0572	Macroscopic visual analysis, petrographic and thin section analysis
20	F2040	Macroscopic visual analysis, petrographic and thin section analysis
21	F0681	Macroscopic visual analysis, petrographic and thin section analysis
22	F2366	Macroscopic visual analysis, petrographic and thin section analysis
23	F2936	Macroscopic visual analysis, petrographic and thin section analysis
24	F3067	Macroscopic visual analysis, petrographic and thin section analysis

To test the validity of the MVA, one flake from each group was thin-sectioned (See Table 2). During internal examinations with a stereo microscope at 10X magnification, Flakes No. 21 and No. 23, revealed dissimilar internal textures. Flake No. 21 exhibited a smooth internal texture, while Flake No. 23 had a coarse and/or bumpy internal surface texture not comparable to flake No. 21. The petrographic analysis also noted differences in these flakes, see Table 3 and Appendix II.

Table 2: Macroscopic Visual Analysis (MVA) of Lithic Flakes for Petrographic Analysis.

Flake No. / MVA Group No.	Exterior Colour (Weathered)	Interior Colour (Fresh)	Grain Size (mm)	Internal Surface Texture
19 Group 1	10YR 2/1 Black	10YR 2/1 Black	cryptocrystalline <0.0002 mm	aphanitic
20 Group 2	2.5Y 4/1 Dark Grey	2.5Y 3/1 VeryDark Grey	medium-grained 1-5 mm	phaneritic
21 Group 3	10YR 2/1 Black	10YR 2/1 Black	microcrystalline fine-grained 0.1-1.0 mm	aphanitic
22 Group 4	10YR 2/1 Black	10YR 7/1 Light Grey	microcrystalline fine-grained 0.1-1.0 mm	aphanitic
23 Group 5	10YR 2/1 Black	10YR 2/1 Black	microcrystalline fine-grained 0.1-1.0 mm	aphanitic
24 Group 6	2.5Y 2.5/1 Black	10YR 2/1 Black	microcrystalline fine-grained 0.1-1.0 mm	aphanitic

Note: Physical and visual characteristics of flakes selected for microscopic analysis: external and internal colour; crystal grain size; and internal surface texture. External and internal colour identification based on Munsell Soil Colour Charts. Crystal grain size and interior textural surface were determined using a stereomicroscope at 10x magnification and a transparent metric ruler.

6.3 Petrographic Analysis

Payne (2006) determined there is petrographic variation within the six-flake sample that he examined, and he identified all as basalt rocks. Different types of basalt contain size variations of crystals (i.e., clinopyroxene, orthopyroxene, plagioclase, and apatite). The terms non-porphyritic or slightly porphyritic refer to crystallization of minerals during the cooling stages of magma before reaching the lithosphere. The larger crystals (phenocrysts) are formed early in the deep- seated magma chamber before the lava reaches the surface, at which time the remaining liquid crystallizes quickly to form a much finer-grained groundmass. Phenocrysts represent the first minerals to crystallize out of magma, indicating its chemical composition.

A first-order tool for differentiating basaltic rocks is the composition and nature of phenocrysts. Payne classified samples as basalt based on the presence of plagioclase, clinopyroxene, and orthopyroxene phenocrysts, minerals typically associated with mafic (basaltic) rocks. However, he also noted that these phenocrysts represent five percent of each rock or less and that the extremely fine-grained matrix representing over 95% of each rock is not typical of basalt.

Basalt containing orthopyroxene phenocrysts originates from tholeiitic magma with a different chemical composition than basalts containing clinopyroxene phenocrysts, which originate in general from a calc-alkaline magma. Based on the microscopic examination of these two types of phenocrysts five samples were classified into two different groups of volcanic rock as shown in Table 3. Payne concluded five of the six samples originated from two different magmas. A sixth (No. 21) sample did not match or have comparative minerals to the other five samples.

Both the macroscopic visual assessment (e.g., six groups) and the microscopic analyses (e.g., two groups) indicate these samples are distinct and suggest that they originate from more than one rock type. Due to the size of the flakes after thin sectioning, it was not possible to perform further geochemical analysis on these specific samples. Appendix I and II provide additional descriptive data on the petrography.

Table 3: Microscopic Analysis Summary

Flake No.	Rock Type	Phenocrysts	Groundmass (Magma Type)
Type 1a: Massive, Non-Porphyritic to Slightly Porphyritic (Calc-alkaline magma)			
19	basalt	Pl, Cpx	Pl, Opx?, (opaque)
22	basalt	Cpx, Pl	Pl, Opx?, (opaque, Mineral X)
Type 1b: Slightly Porphyritic, Aphanitic, Well Foliated (Calc-alkaline magma)			
20	basalt	Cpx, (Pl)	Lathy Pl., Opx?, (dusty opaque, Mineral X)
Type 1c: Weakly Foliated, Non-Porphyritic to Slightly Porphyritic (Tholeiitic magma)			
24	basalt	Pl, Opx	Pl, Opx, (opaque)
Type 2: Non-Porphyritic, Very Fine Grained (contained no pyroxene phenocrysts)			
21	basalt	Pl, Ap	Pl, Opx? (Ap, opaque)
Type 3: Orthopyroxene Phenocrysts (Tholeiitic magma)			
23	basalt	Opx, (Pl)	Opx, Pl?

Note: Pl = Plagioclase, Cpx = Clinopyroxene, Opx = Orthopyroxene, Ap = Apatite, Mineral X = Unknown Mineral–could not be identified optically because of extremely fine grain size. In the Phenocrysts column, crystals are from greatest to least amount (L-R). The question mark (?) indicates the identification is tentative: insufficient optical data are available for positive identification, mainly because of the extremely fine grain size. An example is opx (?), which means the mineral is orthopyroxene, but insufficient data are available to be certain. Minerals in brackets (e.g., (Pl) are present in relatively minor amounts in both phenocrysts and groundmass. Opaque refers to a mineral that is opaque to transmitted light. For additional information, see Appendix I and II.

6.4 Multidimensional Scaling of Geochemical Results

The multidimensional scaling (MDS) results were based on 47 element concentrations detected through ICP-MS and ES (See Appendix III and IV). The sixteen flakes from the MVA and two additional flakes (see Table 1) were given a random group letter (See Table 4) before being plotted on the two Dimension map to observe how they would plot in their groups (See Figure 7).

Table 4: Macroscopic Visual Analysis Groups.

MVA Groups	MDS Group Symbol	Flake number			MDS Cluster Group
Group 1	U	13	1	5	Group-A
Group 2	V	10			Group-D
Group 3	W	2	12	8	Group-B
Group 4	X	4	6	14	Group D
Group 5	Y	11	16	9	Group-B
Group 6	Z	3	15	7	Group-A
Added Flake	Q	17			Group-A
Added Flake	Q	18			Outlier

Note: Table 4 outlines each flake's group designation in the initial macroscopic visual analysis (MVA) (noted in column 1) and their representation on the MDS plot. In column 2, letters identify flake MDS groups plotted on two-dimensional map (See Figure 7). Column 3-5 shows how MVA flakes were grouped. After MDS plotting each cluster was designated a group letter (e.g., A, B, D, and letter "Q") in column 6. Added flakes = flakes subsampled to assess internal geochemical variability

The MDS dimensions 1 and 2 in Figure 7 demonstrate that these flakes fall into four primary groups (A, B, D, and outlier Q). Groups A, B, and D are flakes that are either similar or identical in element concentrations (e.g., SiO_2) as they lie over top of, or next to each other. Within each of these groups (e.g., A, B, and D), there are unique differences.

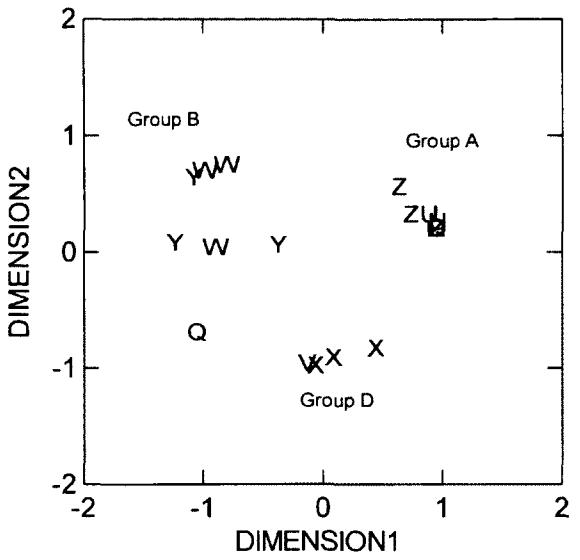

Figure 7: Multidimensional-scaling Plot.

Along dimension 1, letter "Q" is isolated with significant element concentration pointing to a rock type not well represented in the artifact assemblage. The isolation of letters Y W Y in cluster group B; letter Z in cluster group A, and letters X X in cluster group D along dimension 1 and 2 suggests strong dissimilarities in their element concentrations within their cluster groups. The plotting of each cluster group suggests the isolated flakes may represent the same rock type, but with varying levels of element concentration from different locations of a lava flow.

Flakes in Group B are distinct from Groups A and D, but they also demonstrate the greatest dispersion on the MDS plot, and one could argue for two different "B" groups. Flakes showing the strongest relationships are likely the same rock type and possibly originate from the same primary or a secondary provenance. The MDS

dimension 1 and 2 plotting of the 18 flakes shows four cluster groups with one or more flakes isolated from within each group.

6.5 Cluster Analysis of Geochemical Results

The data set is comprised of 18 observations and the trace and rare earth elements (variable) were limited to 15 elements for the CA. A dendrogram can be partitioned subjectively at the discretion of the researcher, however, the small sample size here dictated against partitioning. Ward's method allows for the choice of general clustering based on visual inspection. Therefore, flake clusters are based on visual observations of vertical and horizontal branch distances for each sample. Different methods of measurement (e.g., Euclidian distance measurement) used in large sample studies were not used in this study. Destruction of each flake in preparation for the ICP-MS and –ES removed the opportunity to validate the cluster groups.

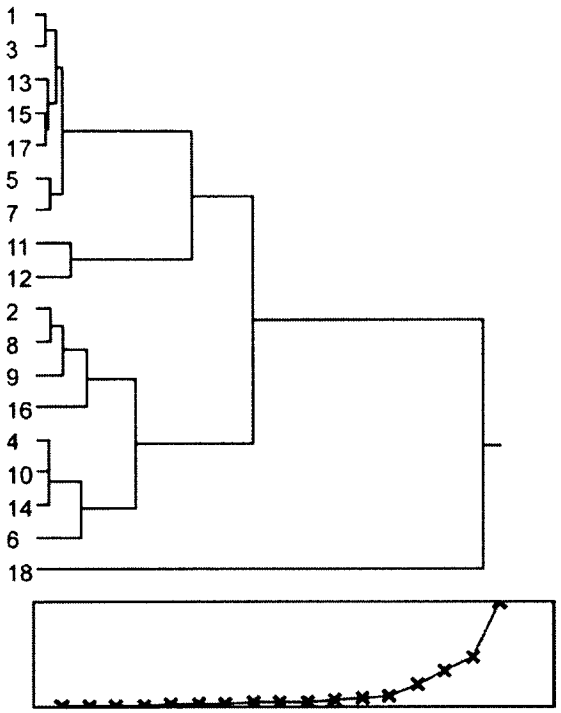

Figure 8: Dendrogram of hierarchical cluster analysis.
The scree plot beneath the dendrogram represents points for each cluster. Each ordinate is the distance bridged to join clusters. There is a break in the cluster where the distance jumps up suggesting natural points to determine the number of clusters.

Hierarchical clustering assumes that each flake is a cluster onto itself. From this point, clusters sharing similarities or the same equal distance on a vertical line are merged until all flakes form one large cluster. Flakes not sharing the same distance on a vertical line are dissimilar to other flakes and are considered as atypical outliers. The criterion for selecting clusters was based on the smallest distance equally shared by two or more flakes from left to right. The CA suggests six fairly well defined flake clusters based on element concentrations. It should be noted that all flakes demonstrated variations in element concentrations while the strongest distinction was represented by flake No. 18. Flakes 1, 3, 13, 15, and 17 constitute the first cluster of flakes. Flakes 5 and 7 are the second cluster. Flakes 11 and 12 are the third cluster. Flakes 2, 8, 9, 16 are the fourth

cluster. Flakes 4, 10, 14, and 6 are the fifth cluster, and 18 is the outlier for group six. The result of using Ward's method demonstrates the shortest horizontal distances share the most-similar element concentrations. Both MDS and CA analyses demonstrate more than one grouping, again suggesting that the sample is likely represented by more than one provenance.

6.6 Internal Homogeneity

Two samples were sectioned and tested for internal homogeneity. Results from the ICP-MS and -ES indicate flakes No. 17 and No. 18 were two different rock types (See letter "Q" in Figure 7), indicated by the major, trace, and rare earth elements (See Appendix V and VI). The results also show consistent element concentrations for each 10g bottle tested for each sample. Most importantly, the tests show that both flakes are internally homogenous, as powders from each artifact section indicate no unique internal differences. From this, the assumption is that all samples are internally homogenous.

6.7 Volcanic Rock Classification

Using a total alkali-silica (TAS) diagram (See Figure 9), flakes were classified into rock types (Figure 10). The fields in the TAS diagram represent a rock classification recommended by the International Union of Geological Sciences (IUGS) Subcommission on the Systematics of Igneous Rocks (Le Bas et al. 1992). Each flake was given a distinct identifying group letter (See Table 4) in anticipation of results from analyses as seen in Figure 7 and 8. The combination of SiO_2 versus $Na_2O + K_2O$ is considered the best chemical parameter for comparing and contrasting igneous rocks (Le Bas et al.

1992). The flakes have high SiO_2 contents (~69 wt %) and low $Na_2O + K_2O$ contents (~8 wt %), as noted in Appendix III. Based on their alkali silica content, most samples appear to be trachydacite and dacite (Figure 10). Single flakes plotted within the rhyolite, andesite, trachyandesite, and basaltic trachyandesite fields. The presence of six different rock types supports the notion that more than one rock type is represented in the Punchaw Lake artifact assemblage.

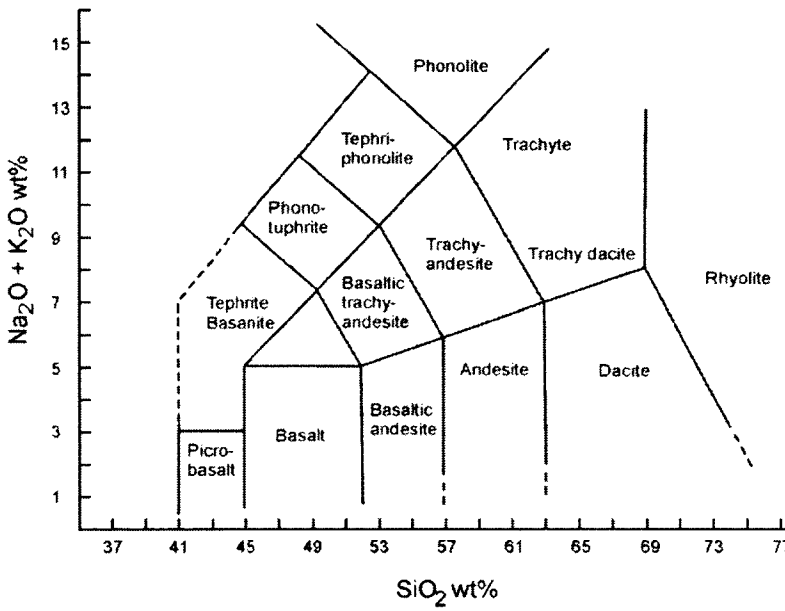

Figure 9: Chemical classification of volcanic rocks using total alkali-silica (TAS) diagram. (Adapted from Le Bas et al. 1992: Figure 1 [a]).

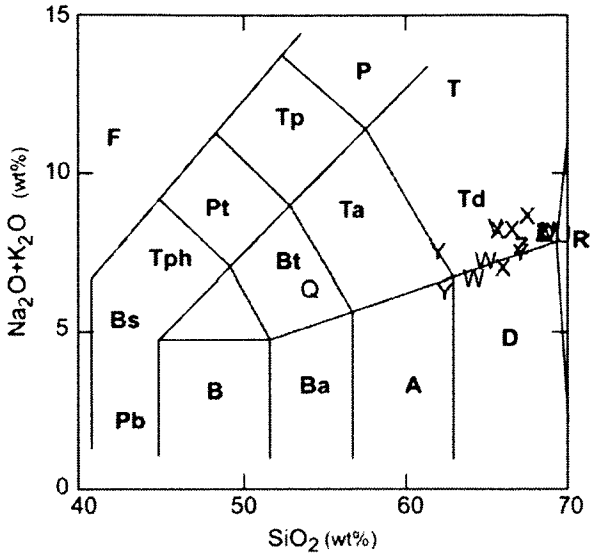

Figure 10: Punchaw Lake samples plotted according to SiO_2 versus Na_2O+K_2O. Samples are identified by their group letters, noted in Table 5. Q is sample 18. Pb (picro-basalt), Bs (basanite), Tph (tephrite), Pt (phonotephrite), F (foidite), P (phonolite), Tp (tephriphonolite), T (trachyte), Td (trachydacite), R (rhyolite), D (dacite), B (basalt), Bt (basaltic trachyandesite), Ba (Basaltic andesite), Tb (trachybasalt), Ta (trachyandesite), and A (andesite). Diagram and field coordinates adapted and taken from Le Bas et al. (1992).

6.8 Discussion

Three different approaches are used to explore variation within the physical make up of the Punchaw Lake assemblage to test the null hypothesis that one provenance is represented. All of the analyses suggest that variation is likely present in the sample. The TAS diagram in Figure 10 plots the majority of flakes within or around the trachydacite field suggesting these flakes may originate from different locations of a single lava flow rather than multiple lava flows. It is possible that flakes originating from one provenance would share a greater similarity in their element concentrations when comparing the MDS and CA results. However, the quantitative results corroborate that enough element dissimilarity exists to support a diversity of rock types in the artifact assemblage. In addition, petrographic thin-section analysis also determined that two different lava flows

(e.g., tholeiitic and calc-alkaline) are represented amongst the six flakes examined. These results imply that tool stone at Punchaw Lake likely represents more than one rock type and likely two different lava flows, therefore, the null hypothesis is rejected.

H_o: *Tool stones found at Punchaw Lake Village site cannot be shown to be lithologically different.*

Hypothesis: *If tool stone was selected and transported from multiple provenances, then this variability should be reflected in the geochemical analyses of artifacts from this site.*

CHAPTER 7: CONCLUSIONS

7.1 Introduction

Previous geochemical analyses of tool stone (Bakewell and Irving 1994; Carlson 1994; Commisso 1999; Evans and Wilmeth 1971; Godfrey-Smith 1985; Greenough et al. 2000, 2004; James et al. 1996; Mallory-Greenough et al. 2002; Nelson et al. 1975; Nelson and Will 1976; Richards 1988; Smith 2004; Wilmeth 1973) by archaeologists have begun to address important issues on British Columbia's long aboriginal history, and these works partially inspired the present project that focuses on samples from the Punchaw Lake Village (FiRs-1) site (ca. 5,000 – 200 ^{14}C yr BP). The site reflects an intensive tool stone exploitation spanning at least 4,000 years starting with the Lochnore Phase and onward through the different horizons of the Plateau Pithouse Tradition. Even though a relatively small area was excavated, the volume of data, the culture history, the diversity of the artifact assemblage, and earliest recognized burial on the site demonstrate an intensive occupation long before European contact (Watson 2011). The artifact assemblage and the site's proximity to well used trails suggests that this site was a stone tool production centre, where raw materials were brought in and exported. Nearby trails would allow the transport and exchange of raw material and/or finished stone tools across the landscape. Projectile points and preforms made from trachydacite and dacite, similar in style to those found at Punchaw Lake, are found on archaeological sites throughout the Nechako Plateau, indicating this rock has been continuously procured by generations of Aboriginal peoples.

7.2 Summary of Results

The need to classify tool stones and provenances has resulted in a battery of analytical methods used by archaeologists to delineate lithological relationships (Milne et al. 2009; Smith 2004). In this analysis, macroscopic visual analysis (MVA), petrographic (microscopic) analysis, inductively coupled plasma mass spectrometry (ICP-MS) and emission spectrometry (ES), and total alkali-silica (TAS) diagram were used to classify volcanic rocks. Preliminary analytical methods (MVA and petrography) provided limited results based on their ability to examine the external and internal composition of each sample. Element concentration data collected from ICP-MS and ES was used for the TAS diagram, multidimensional scaling, and cluster analysis.

Both the MVA and petrography provided a starting point for which to organize a random mixture of flakes into groups based on physical differences. The MVA resulted in six different groups of flakes based on the internal surface texture, crystal size, and colour. To test the validity of the groupings, one flake representing each group was thin-sectioned and examined by a petrographer to determine physical variation. The examiner classified five of six flakes as originating from two different lava flows based on two different types of phenocrysts observed within different samples. Even though the number of groupings was different in each case, both MVA and petrography were taken as preliminary revelations that these flakes are made on different tool stone materials. In other words, more than one provenance is likely represented. The next round featured an elemental analysis on a larger sample, to test the variation present.

Fifty-six elements in a sample of 18 flakes were measured using ICP-MS and ES, which provided primary data to examine variations, based on element concentrations.

Ratios of SiO_2 versus Na_2O/K_2O (wt. %) suggest that the majority of flakes (classified on a TAS diagram) are made on trachydacite and dacite while remaining flakes plotted in surrounding fields (e.g., trachyandesite, andesite, rhyolite, and basaltic trachyandesite). Based on past geochemical analyses (Hunt 1991; Smith 2004; Nelson et al. 1975) and tests in the current project, there is insufficient evidence to indicate that weathered surfaces have an impact on these results. The abundance of trachydacite suggests Aboriginal people consistently endeavoured to procure a flakeable tool stone. The large amount of trachydacite flakes may also mean that large volumes of tool stone were procured from the same location or provenance, although this needs further testing.

Quantitative analyses were used to interpret the element concentration data. Multidimensional Scaling identified up to four different clusters of flakes in a two-dimension plot. In some cases, the two-dimension plot isolated some flakes as outliers within their groups suggesting these flakes may be related based on specific element concentrations within their composition, however, they may still originate from a different lava flow. A cluster analysis indicates that multiple flakes do share element concentration similarities or act as outliers, but representing six different clusters.

These results indicate more than one rock type and/or provenance (lava flow) exists within the artifact assemblage. Different rock types within the artifact assemblage are characterized primarily by their SiO_2 content (wt. %). If these data are accurate, multiple types of volcanic rock and/or provenances are represented at the Punchaw Lake Village site. The volume of flakes in the artifact assemblage could suggest that the tool stone material is local, but this is highly speculative and needs to be tested.

7.3 Discussion

Ethnohistoric and ethnographic observations of exchange, individual carrying capacity, methods of resource transport, established trail systems; archaeological evidence of varieties of tool stone material, and Post-contact artifacts suggests the inhabitants of Punchaw Lake village site were likely part of a large social and exchange network that operated over the larger landscape. Forms of exchange observed ethnohistorically in the Interior and Columbia Plateau are similar to those used by hunter-gatherer societies in Australia, and suggest these exchange networks were established long before Contact throughout both regions. The existence of exotic resources such as shell (Galm 1994) and obsidian (Carlson 1994; Wright and Carlson 1987) far from their origin illustrates long-distance exchange amongst Aboriginal people.

The proximity of two well-used trails at Punchaw Lake that pre-date European contact, and the large volume of trachydacite and dacite tool stone suggests this raw material was transported and exchanged. Trails recorded historically were the same used traditionally by Aboriginal people before European contact as observed by Mackenzie (2001) when he crossed the Nechako Plateau. Although the present study did not identify the sources from which tool stone was obtained, it does show that the inhabitants of Punchaw village were obtaining raw materials from multiple provenances. This highlights even further the importance of trails as a primary mechanism to transport raw materials and other necessities. Given the great time depth in the use of this village location, and that stone tools played an important role in this success, the next step will be to identify the actual sources for tool stone, so that a more detailed picture on land use and exchange may begin to emerge.

7.4 Implications for Hypothesis

Geochemical evidence supports the hypothesis (discussed on page 63) that the Punchaw Lake flakes represent different rock types originating from more than one provenance. The presence of up to six different rock types in the rock classification suggests Aboriginal people in the area employed a broad range of procurement strategies to obtain tool stone from various provenances and/or from opportunistic encounters when traversing the landscape. Different rock types potentially represent different strategies for stone tool manufacturing throughout the different cultural periods seen within the Punchaw Lake artifact assemblage.

Despite the lack of field data available to identify the provenances of tool stone this research shows that a minimum of two groups or provenances are represented at Punchaw Lake. The presence of trachydacite and dacite at Punchaw Lake can only be explained as evidence of transport and/or exchange of resources. The volume of materials, the stratigraphy and the radiocarbon chronology suggest that the Punchaw Lake Village was actively used on a repeated basis through several cultural time periods, and that the immediate region was recognized as a multi-resource rich locality from one generation of Aboriginal people to the next.

7.5 Conclusions and Future Research

To date relatively few archaeological provenance studies have been completed in the Interior Plateau (Commisso 1999; Heffner 2010; Mallory-Greenough et al. 2002; Greenough et al. 2004; Vivian 1992) and coastal regions (Smith 2004), of BC, however, the interest continues to grow. This thesis is part of an initial step towards the expansion

of sourcing studies in north-central British Columbia. That said, there are limitations to the present study.

The first limitation is the lack of archaeological exploration in the study area to identify primary and/or secondary provenances, which has resulted in the lack of a comparative library of provenances so far. There was no opportunity for samples or geochemical data in the present sample to be compared. There are suggestions on where potential secondary provenances could be available, but no specific location has been determined.

The second limitation is the sample size selected to geochemically characterize the assemblage. The small sample size is sufficient for an exploratory study with limited funding, however, the results of the analyses suggests a larger flake sample could potentially enhance this research.

A third limitation is the destruction of artifacts to determine petrography and element concentrations in each flake. ICP-MS and ES require samples to be destroyed, but are efficient for testing for a large variety of elements in a very short period. The size of flakes used did not allow excess material to be available for multiple analyses. This was especially apparent in the case of the flakes used for petrographic analysis. The destruction of artifacts has been an issue for past researchers who have used non-destructive methods to preserve artifacts in their study resulting in artifact preservation for later studies (Rudy Reimer, personal communication 2011; Smith 2004). Despite these limitations the present research has been successful in showing that there is some variability present in the make up of the Punchaw Lake tool stone.

The following points to be considered for future development:

(i) Developing regional databases of primary and secondary provenances could potentially lead to inferences on settlement patterns and movement throughout a specific region.

(ii) Standard analytical techniques should be established for geochemical research on stone tools across BC. This would allow the comparison and inclusion of data collected from other regions.

(iii) Studies will benefit from greater cooperation with archaeologists in Cultural Resource Management, through the active sharing of information regarding the identification of primary and/or secondary provenances. This would ideally include the contribution of geological materials and/or flake samples to assist in the development of a regional database of provenances.

The Punchaw Lake Village site will continue to present questions on the selection and use of trachydacite and dacite as a tool stone for several millennia. The geochemical study of tool stone and its distribution across the landscape can only add more to our understanding of the occupants of Punchaw Lake Village site (e.g., land use, preference for raw material, and technological change). It is hoped that this research will encourage more rigorous sampling and testing of lithics to determine their provenance and provide a template for future research. This investigation has contributed new data that will hopefully encourage further field research in tool stone varieties in BC; and provenance studies of tool stone from archaeological sites within BC.

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APPENDIX I: PETROGRAPHIC ANALYSIS

Description of Petrographic Analysis

Note Abbreviations:
Pl = Plagioclase
Cpx = Clinopyroxene
Opx = Orthopyroxene
Ap = Apatite
Mineral X = Unknown Mineral–could not be identified optically because of extremely fine grain size.
The question mark (?) indicates the identification is tentative: insufficient optical data are available for positive identification, mainly because of the extremely fine grain size. An example is opx? Which means the mineral is orthopyroxene, but insufficient data are available to be certain.
Minerals in brackets (e.g., (Pl) are present in relatively minor amounts in both phenocrysts and groundmass.
Opaque refers to a mineral that is opaque to transmitted light.

Flake No. 19/F0572: Very Slightly Porphyritic Aphanitic Basalt

Minor phenocrysts of plagioclase and clinopyroxene are set in a groundmass of aphanitic plagioclase with disseminated, prismatic grains of a mafic mineral (containing dusty opaque) and minor disseminated opaque.

Mineral	Percentage	Main grain size range (mm)
Phenocrysts		
Plagioclase	0.3%	0.1-0.4
		(One porphyroblast 1 mm across)
Clinopyroxene	0.2	0.2-0.5
Groundmass		
Plagioclase	85-87	0.02-0.04
Mafic mineral	12-15	0.02-0.05 (a few up to 0.1 mm)
Opaque	0.3	0.005-0.01

Plagioclase forms anhedral to subhedral phenocrysts, slightly elongate phenocrysts. One porphyroblast 1 mm across contains inclusions of orthopyroxene (?) (The question mark (?) indicates the identification is tentative) similar to those in the groundmass.

Clinopyroxene forms a few anhedral to subhedral phenocrysts. Some have an overgrowth of groundmass clinopyroxene up to 0.05 mm thick.

The groundmass is dominated by slightly lathy to equant plagioclase gains with no preferred orientation.

Mafic mineral forms disseminated unoriented prismatic grains that contain dusty opaque inclusions. It is colourless with moderate relief, low birefringence, and parallel extinction (length-slow).

Opaque forms minor disseminated grains averaging 0.005-0.01 mm in size.

Flake No. 20/F2040: Clinopyroxene-phyric Flow-Foliated Basalt

Phenocrysts of clinopyroxene and minor phenocrysts of plagioclase are set in a well-foliated groundmass dominated by lathy plagioclase and a mafic mineral (probably orthopyroxene), with abundant disseminated dusty opaque. Mottles are defined by concentrations of cryptocrystalline semi-opaque Mineral X (X = Unknown Mineral).

Mineral	Percentage	Main grain size range (mm)
Phenocrysts		
Clinopyroxene	4-5%	0.2-1
Plagioclase	0.3	0.2-0.3
Groundmass		
Plagioclase	65-70	0.03-0.07 (lathy); 0.005-0.02 (equant)
Mafic mineral	20-25	0.02-0.05
Opaque	1-2	0.003-0.005
Mineral X	2-3	cryptocrystalline

Clinopyroxene forms subhedral to euhedral phenocrysts that are commonly concentrated in clusters. One large cluster is partly rimmed by a zone up to 0.3 mm wide in which the groundmass contains moderately abundant dusty Mineral X (X = Unknown Mineral). A few clusters also contain one or two stubby plagioclase phenocrysts (0.05-0.15 mm).

Plagioclase forms elongate prismatic phenocrysts, most of which are oriented parallel to the flow foliation.

In the groundmass, plagioclase forms lathy grains that show a strongly preferred orientation that defines the flow foliation. Interstitial to these is much finer grained, equant plagioclase.

The mafic mineral (possibly orthopyroxene) forms stubby prismatic to equant grains intergrown with plagioclase and commonly containing dusty inclusions of opaque.

Opaque forms disseminated equant grains.

Mineral X (X = Unknown Mineral), a cryptocrystalline, semi-opaque material is concentrated in irregular to subrounded mottles, mainly from 0.3-1 mm in size, in which it is intergrown mainly with groundmass plagioclase and mafic mineral. In larger mottles, Mineral X(X = Unknown Mineral) is concentrated moderately to strongly in an outer zone and is less abundant at the core.

Flake No. 21/F0681: Aphanitic Basalt, Flow Foliation

Scattered phenocrysts of plagioclase and minor phenocrysts of apatite are set in a moderately flow-banded groundmass of plagioclase, a mafic mineral (possibly orthopyroxene), and minor apatite and opaque; the groundmass is moderately coarser grained than that of Sample FiRs 0572. A few patches of groundmass contain Mineral X (X = Unknown Mineral) and limonite. A wispy veinlet is of plagioclase.

Mineral	Percentage	Main grain size range (mm)
Phenocrysts		
Plagioclase	1- 2%	0.07-0.2 (a few up to 0.4 mm)
Apatite	minor	0.1-0.2 (a few up to 0.3 mm)
Groundmass		
Plagioclase	77-80	0.005-0.05
Mafic mineral	15-17	0.015-0.03
Mineral X	0.3	cryptocrystalline
Apatite	0.3	0.05-0.08
Opaque	1	0.03-0.07
Limonite	minor	cryptocrystalline
Veinlet		
Plagioclase	minor	0.01-0.02

Plagioclase forms scattered, prismatic phenocrysts, many of which are elongated parallel to the flow foliation.

Apatite forms anhedral to euhedral prismatic phenocrysts, many of which contain abundant dusty semi-opaque grains that give the apatite grain a medium to dark brownish grey colour.

In the groundmass, plagioclase forms 20-30 percent lathy grains, many of which are in parallel orientation and define the flow foliation.

The mafic mineral (possibly orthopyroxene) forms prismatic to acicular grains intergrown with groundmass plagioclase; some are oriented parallel to the flow foliation.

A few patches up to 2 mm across contain moderately abundant cryptocrystalline Mineral X (X = Unknown Mineral) intergrown with the other groundmass minerals; some of these patches also contain limonite. Opaque forms equant to slightly elongate grains and clusters of a few grains that show no preferential orientation relative to the flow foliation. One opaque patch, 0.6 mm long by 0.2 mm wide, is surrounded by groundmass that contains slightly more opaque than further from the patch. A wispy veinlet 0.01 mm wide is of plagioclase.

Flake No. 22/F2366: Slightly Porphyritic Aphanitic Basalt

Phenocrysts of clinopyroxene and plagioclase are set in an unfoliated groundmass dominated by plagioclase and a prismatic mafic mineral (possibly orthopyroxene) with disseminated opaque and a few patches of Mineral X (X = Unknown Mineral).

Mineral	Percentage	Main grain size range (mm)
Phenocrysts		
Clinopyroxene	2- 3%	0.2-0.5
Plagioclase	2	0.1-0.5
Groundmass		
Plagioclase	70-75	0.03-0.07 (lathy); 0.005-0.02 (equant)
Mafic mineral	17-20	0.02-0.04
Opaque	0.3	0.003-0.005
Mineral X	0.3	cryptocrystalline

Clinopyroxene forms anhedral to subhedral, equant to prismatic phenocrysts, some of which are concentrated in clusters with plagioclase.

Plagioclase forms subhedral to euhedral, prismatic phenocrysts, some of which are concentrated in clusters with clinopyroxene. A few show delicate oscillatory growth zones in a narrow composition range. The groundmass is dominated by unoriented, slightly lathy to equant plagioclase.

The mafic mineral forms subhedral, prismatic, colourless grains with R.I. about 1.65 and very low birefringence; it has parallel extinction and is length-slow. Opaque forms disseminated equant grains. Mineral X (X = Unknown Mineral) is concentrated in mottles up to 1 mm in size, and is commonly adjacent to phenocrysts of clinopyroxene. The groundmass is very similar to that of Sample FiRs-1 0572.

Flake No. 23/F2936: Slightly Porphyritic Aphanitic Basalt

Minor elongate phenocrysts of orthopyroxene and a few of plagioclase are set in an unoriented groundmass containing abundant much smaller, acicular orthopyroxene grains in a matrix of cryptocrystalline plagioclase(?) (The question mark (?) indicates the identification is tentative).

Mineral	Percentage	Main grain size range (mm)
Phenocrysts		
Orthopyroxene	3- 4%	0.2-0.5
Plagioclase	minor	0.07-0.15
Groundmass		
Plagioclase	65-70	cryptocrystalline
Clinopyroxene	25-30	0.05-0.1
Opaque	trace	0.005-0.01

Orthopyroxene forms elongate prismatic to acicular, unoriented phenocrysts.

Plagioclase forms a few stubby prismatic phenocrysts, in part associated with those of orthopyroxene.

The groundmass contains abundant, unoriented acicular to prismatic grains of orthopyroxene in a matrix of cryptocrystalline, equant plagioclase (?) (The question mark (?) indicates the identification is tentative) with low relief. A vague colour-banded flow foliation is seen in the scanned section, but it is not obvious in the thin section.
Opaque forms a few disseminated, equant grains.

Flake No. 24/ F3067: Aphanitic Basalt

Minor phenocrysts of plagioclase are set in a groundmass of anhedral plagioclase and stubby prismatic grains of orthopyroxene with minor opaque. The rock has a weak flow foliation.

Mineral	Percentage	Main grain size range (mm)
Phenocrysts		
Plagioclase	0.5%	0.07-0.12
Orthopyroxene	0.2	0.7
Groundmass		
Plagioclase	60-65	0.01-0.03
Orthopyroxene	25-30	0.02-0.05
Opaque	1- 2	0.03-0.05
Cavities	3- 4	0.1-0.3

Plagioclase forms scattered, elongate small prismatic phenocrysts.

Orthopyroxene forms one anhedral phenocryst that is moderately embayed by the groundmass.

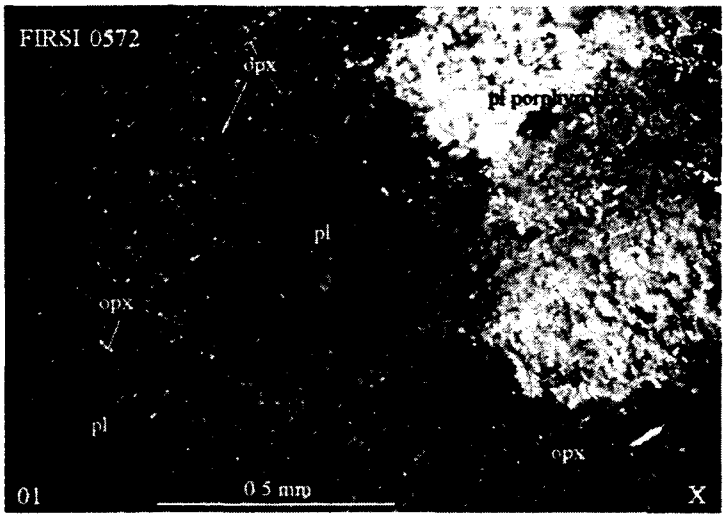
In the groundmass, plagioclase and orthopyroxene both form stubby prismatic grains that are moderately oriented with the plagioclase phenocrysts to define a weak flow foliation. Plagioclase (?) (The question mark (?) indicates the identification is tentative) and/or volcanic glass form interstitial grains/patches to the prismatic grains; some of this material has a light brown colour, probably from iron oxide.

Opaque forms disseminated equant grains (0.003-0.005 mm) and scattered patches up to 0.05 mm in size.

Slightly irregular, equant cavities are from 0.1-0.3 mm in size.

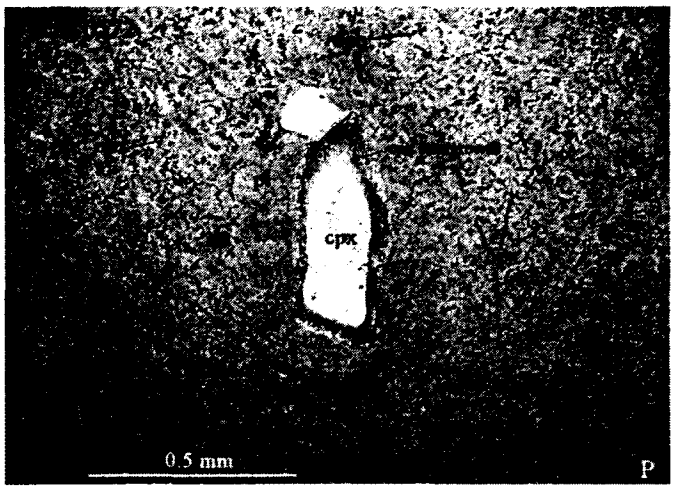
APPENDIX II: PETROGRAPHIC PHOTOMICROGRAPHS

Photomicrograph of No. 19/F0572



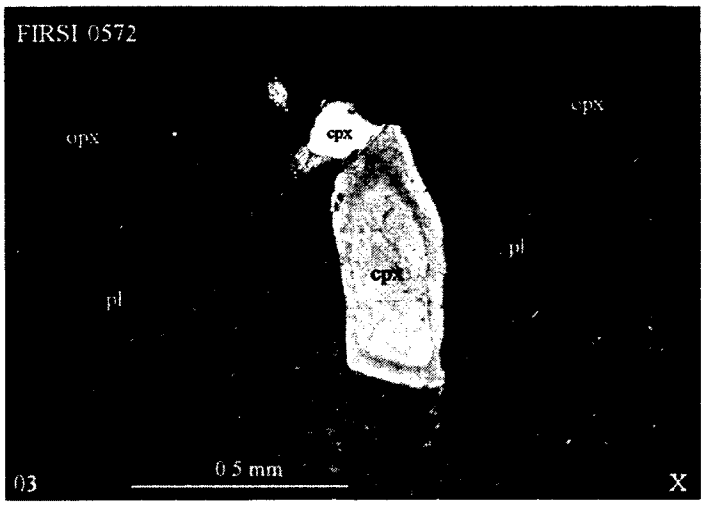
Irregular plagioclase porphyroblast with disseminated prismatic inclusions of orthopyroxene (?). (The question mark (?) indicates the identification is tentative), in a groundmass of plagioclase with similar prismatic grains of orthopyroxene (?) and minor opaque.

Photomicrograph of No. 19/F0572



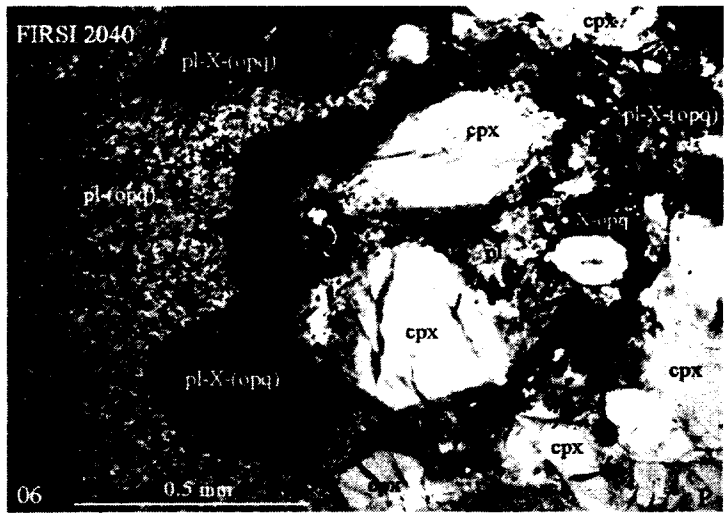
Clinopyroxene phenocryst with overgrowth of clinopyroxene, in a groundmass of plagioclase with prismatic orthopyroxene (?). (The question mark (?) indicates the identification is tentative) and minor disseminated opaque.

Photomicrograph of No. 19/F0572



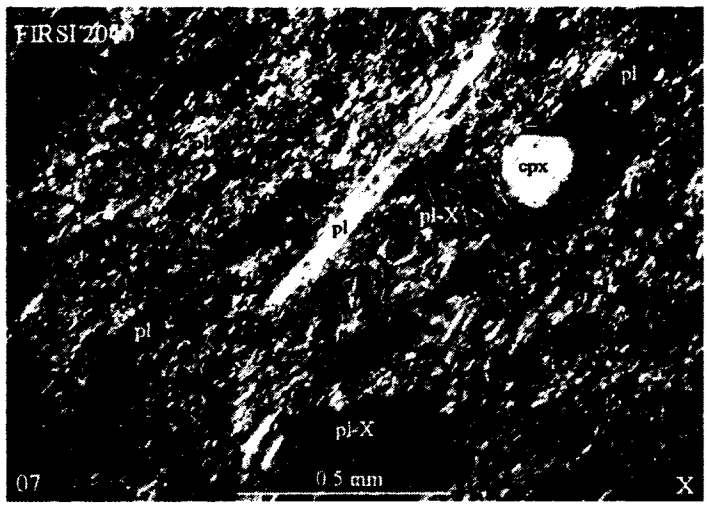
Similar view to previous photo; crossed nicols.

Photomicrograph of No. 20/F2040



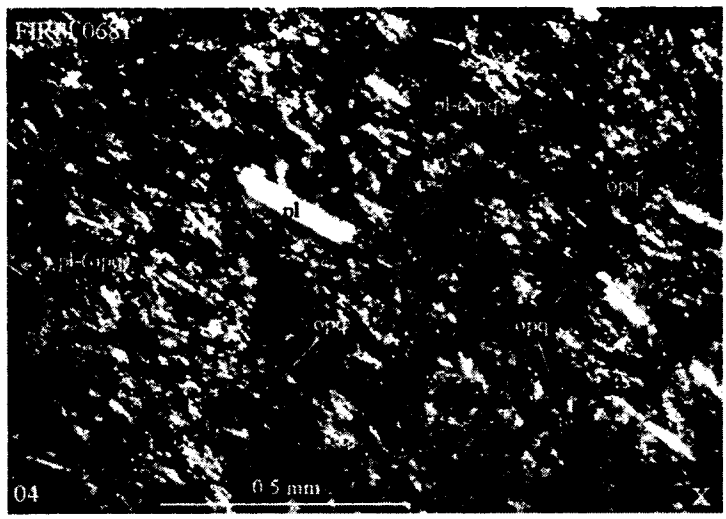
Cluster of clinopyroxene phenocrysts with interstitial plagioclase, in a groundmass of plagioclase and disseminated opaque; partial rim around the clinopyroxene cluster of Mineral X (X = Unknown Mineral) intergrown with groundmass plagioclase.

Photomicrograph of No. 20/F2040



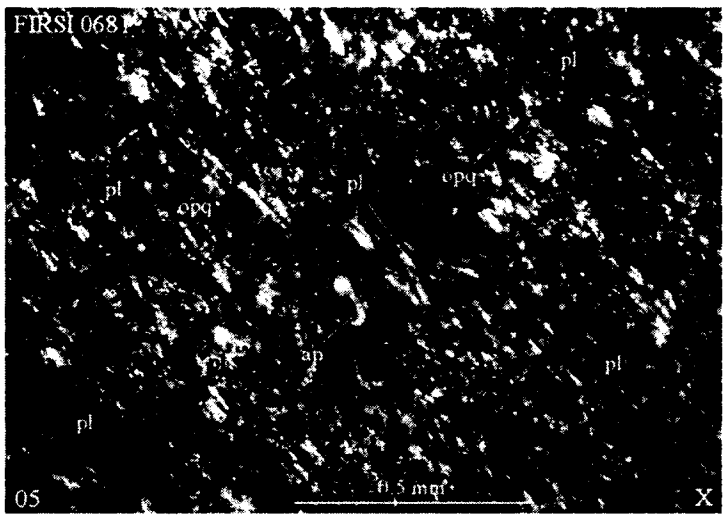
An elongate plagioclase phenocryst (aligned parallel to flow foliation) and an equant clinopyroxene phenocryst, in a groundmass dominated by lathy to equant plagioclase with dusty disseminated pyrite; a few mottles contain concentrations of Mineral X (X = Unknown Mineral) intergrown with groundmass plagioclase.

Photomicrograph of No. 21/F0681



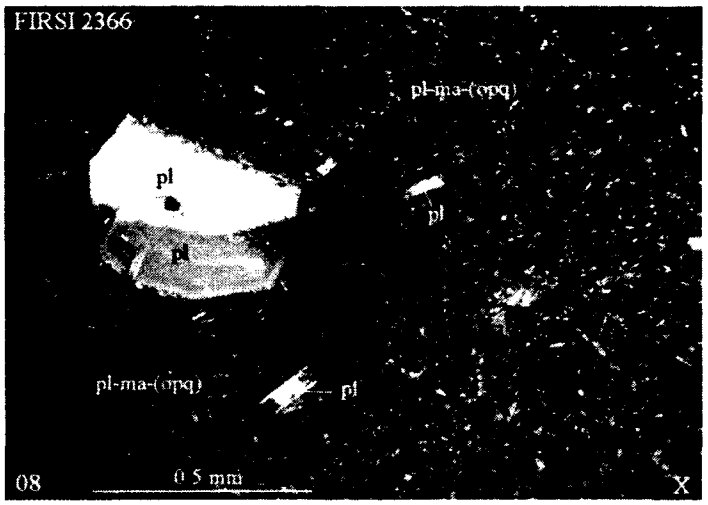
Plagioclase phenocryst in a groundmass of lathy to equant plagioclase and mafic mineral with minor disseminated opaque; the phenocryst and lathy plagioclase show a preferred orientation that defines the flow foliation.

Photomicrograph of No. 21/F0681



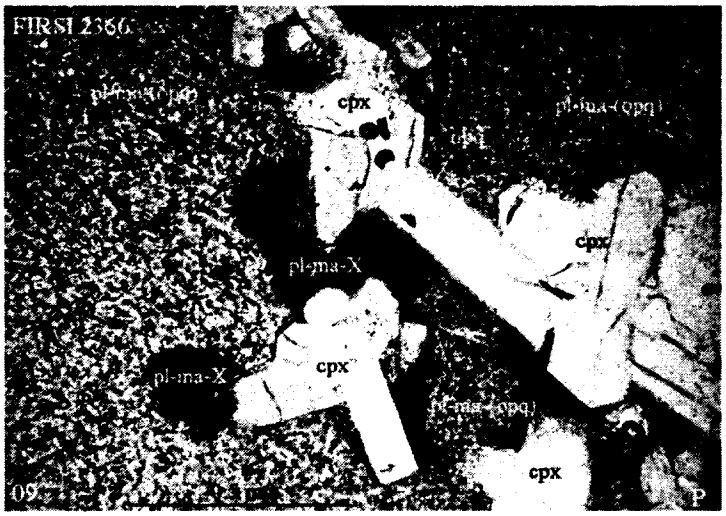
Apatite phenocryst and ragged prismatic phenocrysts of plagioclase in a groundmass of lathy to equant plagioclase with lesser mafic mineral and minor opaque grains; elongate grains show a moderately preferred orientation that defines the flow foliation.

Photomicrograph of No. 22/F2366



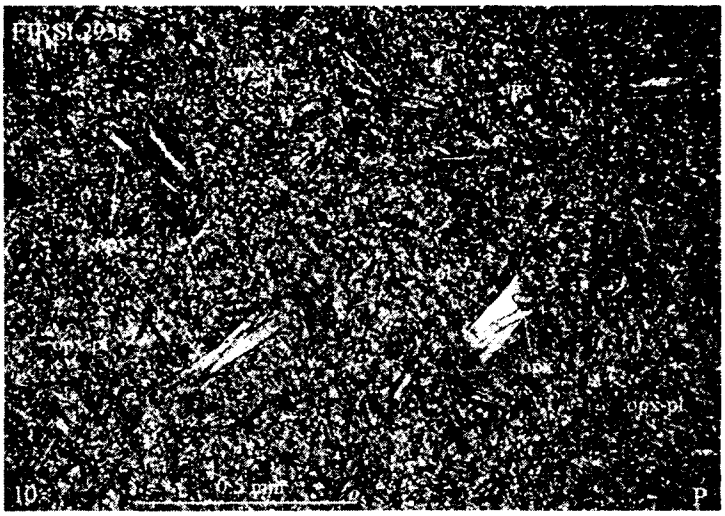
Two adjacent large plagioclase phenocrysts, one showing oscillatory growth zoning, and two small phenocrysts of plagioclase, in a groundmass of plagioclase-mafic mineral with minor disseminated opaque.

Photomicrograph of No. 23/F2366



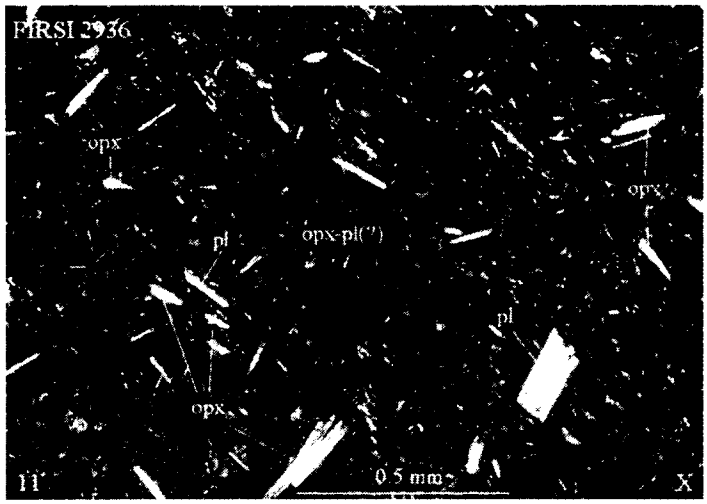
Cluster of clinopyroxene phenocrysts, in a groundmass of plagioclase-mafic mineral and disseminated opaque; patches of Mineral X (X = Unknown Mineral) overprint the groundmass bordering some of the phenocrysts.

Photomicrograph of No. 23/F2936



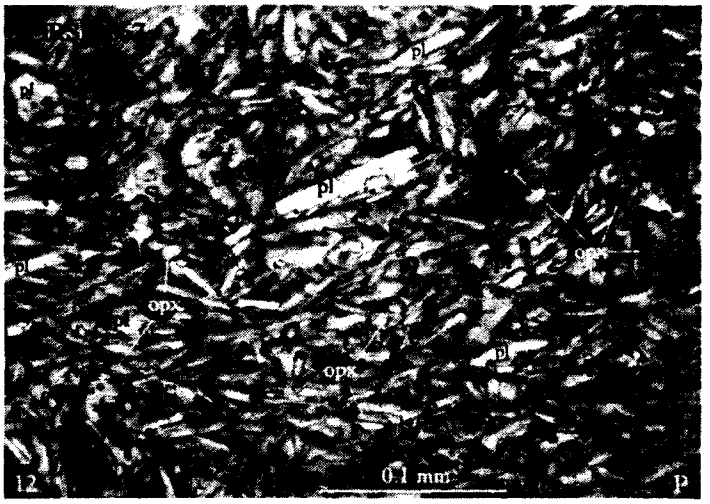
Phenocrysts of orthopyroxene and one of plagioclase, in a groundmass containing acicular orthopyroxene grains intergrown with interstitial devitrified volcanic glass or plagioclase.

Photomicrograph of No. 23/F2936



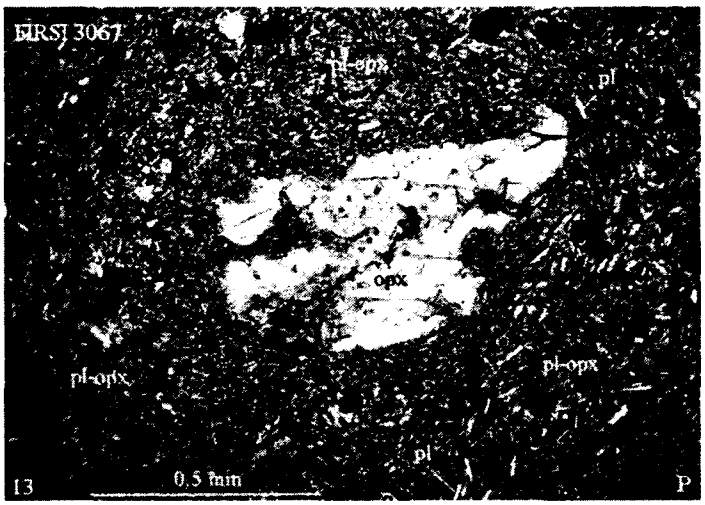
Nearly the same view as previous photo; crossed nicols.

Photomicrograph of No. 24/F3067



Plagioclase phenocryst, in a groundmass of finer lathy to equant plagioclase and orthopyroxene with disseminated opaque grains.

Photomicrograph of No. 24/F3067



Ragged, embayed orthopyroxene phenocryst and a few small plagioclase phenocrysts, in a groundmass of plagioclase-orthopyroxene; brown and black spots are cavities partly filled with non-reflective material of uncertain origin, which probably formed during section preparation.

APPENDIX III: ELEMENT DATA FROM INDUCTIVELY COUPLED PLASAMA MASS SPECTROMETRY AND EMMISSION SPECTROMETRY

Table 5: Major element analysis for selected Punchaw Lake samples.

ELEMENT	SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	Na_2O	K_2O	TiO_2
Flake No.	%	%	%	%	%	%	%	%
1	68.33	15.65	2.96	0.96	2.78	3.87	4.13	0.42
2	64.02	15.49	5.01	2.91	4.64	3.65	3.02	0.61
3	67.06	15.64	4.08	1.41	2.81	3.66	3.96	0.45
4	65.60	16.99	3.69	1.12	3.14	4.78	3.35	0.5
5	68.62	15.54	3.02	0.9	2.83	3.97	4.18	0.43
6	67.38	16.63	2.88	0.83	2.37	4.86	3.72	0.43
7	68.23	15.61	3	0.97	2.87	3.89	4.14	0.44
8	64.01	15.47	5.06	2.89	4.59	3.63	2.96	0.62
9	62.30	15.59	5.58	3.64	5.22	3.55	2.66	0.65
10	65.45	17.11	3.69	1.14	3.07	4.86	3.37	0.52
11	67.04	16.09	3.25	1.56	3.47	4.24	3.2	0.49
12	64.75	16.13	4.23	2.34	4.16	4.66	2.53	0.7
13	69.56	15.3	2.75	0.84	2.57	3.98	4.06	0.39
14	66.47	16.79	3.46	1	2.87	4.81	3.36	0.48
15	68.48	15.58	2.98	0.95	2.83	4.02	4.06	0.43
16	61.92	16.44	5.71	2.82	4.33	4.48	2.99	0.74

Table 5: Major element analysis for selected Punchaw Lake samples (continued).

ELEMENT	MnO	Cr_2O_3	Ni	Sc	LOI	TOT/C	TOT/S	SUM
Flake No.	%	%	ppm	ppm	%	%	%	%
1	0.05	0.002	<5	6	0.4	0.02	<.01	99.70
2	0.09	0.01	17	13	0.1	0.03	<.01	99.71
3	0.07	0.01	8	8	0.4	0.01	<.01	99.70
4	0.11	<.001	<5	5	0.1	0.03	<.01	99.65
5	0.05	<.001	<5	6	0.1	0.01	<.01	99.79
6	0.09	0.001	<5	3	0.2	0.01	<.01	99.62
7	0.05	0.001	<5	6	0.3	0.02	<.01	99.67
8	0.09	0.01	18	13	0.1	0.01	<.01	99.60
9	0.1	0.013	35	15	0.2	0.02	<.01	99.65
10	0.11	<.001	<5	5	0.2	0.05	0.01	99.79
11	0.04	0.004	15	6	0.1	0.01	<.01	99.67
12	0.06	0.009	25	9	0.1	0.01	<.01	99.93
13	0.04	0.002	8	5	0.2	<.01	<.01	99.83
14	0.1	0.001	8	4	0.2	0.04	<.01	99.79
15	0.05	0.001	10	6	0.3	0.03	<.01	99.83
16	0.12	0.014	36	11	0.1	0.04	0.01	99.94

Table 6: Trace and rare earth elements for Punchaw Lake samples

ELEMENT	Ba	Be	Co	Cs	Ga	Hf	Nb	Rb	Sn	Sr	Ta	Th
Flake No.	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
1	1170.3	2	5.5	2.8	16.8	5.3	8.2	134	1	375.2	0.7	13
2	1956.3	2	16.9	2.6	17.6	5.2	7.5	78.6	1	366	0.6	7.1
3	1187	2	6.3	4.9	17.6	5.5	7.8	137.5	2	376	0.7	12.4
4	1380.5	2	3.5	3.3	18.1	5.9	10.9	90.6	1	526.3	0.7	6.4
5	1310.2	2	5.5	2.8	16.9	5.9	8.3	132.8	1	372.5	0.9	12.6
6	1562.4	2	1.2	3	18.4	7.2	11.9	104.3	1	486.5	0.7	7.9
7	1318	2	5.8	2.9	16.6	5.5	7.9	128.7	1	364.3	0.7	11.8
8	1941.6	2	15.7	2.6	16.4	4.8	7.3	75.4	1	347.9	0.6	7.3
9	1639	2	19.4	2.3	16.7	4.5	6.3	67.7	1	328.8	0.5	6.8
10	1354.4	2	3.8	3.3	18.1	6	10.1	88.5	1	517.4	0.7	6.6
11	1237.3	1	8.9	2.6	19.7	3.6	3.7	82.2	1	632.8	0.3	5.6
12	813.4	2	12	1.7	20.9	4.4	4.8	60.3	1	569.4	0.3	6.4
13	1312.8	1	5.1	3.4	18.7	5.8	8.6	141.6	1	385.1	0.7	14.7
14	1360.3	2	3.6	2.9	18.7	6.4	10.4	88.3	1	502.5	0.7	6.7
15	1204.4	2	5.5	2.9	18.3	5.7	8.3	131.8	1	388	0.7	14.2
16	1154.9	2	17.7	2.1	18.5	4.7	9.9	68.2	1	472.7	0.6	5.1

Table 6: Trace and rare earth elements for Punchaw Lake samples (continued).

ELEMENT	U	V	W	Zr	Y	La	Ce	Pr	Nd	Sm	Eu	Gd
Flake No.	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
1	5.1	54	1.1	200.5	11.7	26.3	52.1	6	23.1	3.9	0.88	2.7
2	3.1	93	0.7	187.4	19.3	23.8	46.1	5.33	21.4	3.7	1.25	3.53
3	4.8	68	1.6	196.8	11.6	25.9	51	5.9	22.5	3.5	0.84	2.57
4	3.4	27	0.9	229.9	19.4	28	58.7	7.28	30.4	5.2	1.4	3.96
5	5	53	1.4	200.6	11.7	29.4	57.6	6.92	26.9	4.4	0.99	2.92
6	3.6	12	0.9	294.6	18.4	29.7	61.1	7.38	30.3	5	1.39	3.61
7	4.8	53	1.8	199.3	12.4	28.1	55.9	6.4	25.8	4	0.94	2.76
8	3.1	88	0.6	180.2	20.4	23.2	45.2	5.3	21	4.1	1.2	3.6
9	2.5	103	0.6	157.3	18.6	20	39.8	4.58	18.7	3.6	1.05	3.29
10	3.2	27	0.8	216	18.7	27.1	57.3	7.09	29	5.3	1.47	3.98
11	2.8	70	0.3	133.1	5.4	17.6	36.2	4.26	17.7	2.8	0.77	1.84
12	2.9	92	0.6	158.6	8.6	19.4	41.6	5.15	20.7	3.6	1.01	2.76
13	5.2	54	1	204.7	11.5	26.7	54.6	6.19	23.2	4.1	0.87	2.75
14	3.3	22	1	229.7	17.9	28	60.8	7.33	29.6	5.3	1.32	4.18
15	4.8	58	1	202.3	11.2	25.7	53.4	6.17	24.9	3.8	0.9	2.82
16	2.4	108	1	161.1	19.6	25.9	58.2	7.26	29.5	5.4	1.48	4.57

Table 6: Trace and rare earth elements for Punchaw Lake samples (continued).

ELEMENT	Tb	Dy	Ho	Er	Tm	Yb	Lu	Ho	Mo	Cu	Pb	Zn
Flake No.	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
1	0.39	2.13	0.37	1.07	0.17	0.96	0.16	0.37	0.3	7.9	2.2	17
2	0.55	3.22	0.63	1.97	0.3	2.13	0.32	0.63	0.3	15.2	5.9	22
3	0.41	2.13	0.39	1.2	0.16	1.1	0.17	0.39	0.4	6.5	1.4	24
4	0.64	3.19	0.59	1.83	0.27	1.96	0.3	0.59	0.3	3.9	1.7	35
5	0.39	2.09	0.39	1.09	0.16	1.02	0.16	0.39	0.2	6.5	1.8	14
6	0.56	3.08	0.54	1.75	0.29	1.73	0.31	0.54	0.2	3	1.2	28
7	0.44	2.26	0.37	1.19	0.16	1.08	0.16	0.37	0.3	5.7	2.8	26
8	0.59	3.53	0.7	2.21	0.34	2.19	0.34	0.7	0.3	9.6	1.3	9
9	0.54	3.32	0.6	1.93	0.29	1.96	0.3	0.6	0.4	10.5	1.6	17
10	0.62	3.47	0.6	1.83	0.26	1.77	0.27	0.6	0.4	7.6	2.7	54
11	0.24	1.13	0.17	0.44	0.07	0.4	0.05	0.17	0.2	6	0.7	10
12	0.37	1.81	0.29	0.77	0.1	0.78	0.1	0.29	0.1	17	0.8	16
13	0.4	2.17	0.36	1.09	0.15	1.03	0.16	0.36	0.2	2.7	0.6	10
14	0.65	3.47	0.57	1.78	0.26	1.7	0.28	0.57	0.5	6.7	4	45
15	0.46	2.22	0.36	1.09	0.16	1.01	0.16	0.36	0.2	6.3	2	17
16	0.7	3.88	0.63	1.89	0.27	1.7	0.27	0.63	0.4	22.6	1.1	27

Table 6: Trace and rare earth elements for Punchaw Lake samples (continued).

ELEMENT	Ni	As	Cd	Sb	Bi	Ag	Au	Hg	Tl	Se
Flake No.	ppm	ppm	ppm	ppm	ppm	ppm	ppb	ppm	ppm	ppm
1	3.4	3.9	<.1	0.1	<.1	<.1	<.5	0.01	<.1	<.5
2	4.2	3.6	0.1	0.1	0.1	<.1	0.7	0.03	<.1	<.5
3	7.8	3.4	<.1	0.1	<.1	<.1	0.8	<.01	0.2	<.5
4	1.3	2	0.1	0.1	<.1	<.1	<.5	0.01	<.1	<.5
5	1.4	2.6	<.1	0.2	0.1	<.1	0.6	0.01	<.1	<.5
6	0.7	2.6	<.1	<.1	0.1	<.1	1.2	<.01	<.1	<.5
7	1.4	7.2	0.1	0.2	0.1	<.1	0.8	0.01	<.1	<.5
8	1.8	1.8	0.1	<.1	<.1	<.1	<.5	0.01	0.1	<.5
9	2.9	3.2	<.1	0.1	0.1	<.1	<.5	0.01	<.1	<.5
10	1.5	2.6	<.1	0.3	<.1	<.1	<.5	0.01	0.1	<.5
11	1.9	2.4	<.1	0.1	<.1	<.1	<.5	<.01	<.1	<.5
12	4.3	1.5	<.1	<.1	<.1	<.1	<.5	0.01	<.1	<.5
13	1	2.4	<.1	<.1	<.1	<.1	<.5	<.01	<.1	<.5
14	1.2	4.3	0.1	0.2	<.1	<.1	0.5	0.01	<.1	<.5
15	1.6	2	<.1	0.1	0.1	<.1	0.5	0.01	0.1	<.5
16	6.4	2	<.1	0.1	0.1	<.1	1.3	<.01	<.1	<.5

APPENDIX IV: ELEMENTS USED FOR MULTIDIMENSIONAL SCALING FROM SELECTED PUNCHAW LAKE LITHIC FLAKES.

Notes: Major element oxides in wt. %, trace elements in ppm.

nd = not detected.

LOI = Loss on Ignition, negative value (18) reflects oxidation of Fe that added weight.

Type/Sym. = rock types distinguished by sterormicroscope observation/symbol used on MDS diagrams.

NA = not assigned to a type.

Gp.Sym. = geochemical group and symbol on discrimination diagrams

Table 7: Major elements used for multidimensional scaling from selected lithic flakes.

Flake No.	Group Type/Sym.	Gp./Sym.	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	MnO	MgO
1	G1/U	A	68.33	0.42	15.65	2.96	0.05	0.96
2	G3/W	B	64.02	0.61	15.49	5.01	0.09	2.91
3	G6/Z	A	67.06	0.45	15.64	4.08	0.07	1.41
4	G4/X	D	65.60	0.50	16.99	3.69	0.11	1.12
5	G1/U	A	68.62	0.43	15.54	3.02	0.05	0.90
6	G4/X	D	67.38	0.43	16.63	2.88	0.09	0.83
7	G6/Z	A	68.23	0.44	15.61	3.00	0.05	0.97
8	G3/W	B	64.01	0.62	15.47	5.06	0.09	2.89
9	G5/Y	B	62.30	0.65	15.59	5.58	0.10	3.64
10	G2/V	D	65.45	0.52	17.11	3.69	0.11	1.14
11	G5/Y	B	67.04	0.49	16.09	3.25	0.04	1.56
12	G3/W	B	64.75	0.70	16.13	4.23	0.06	2.34
13	G1/U	A	69.56	0.39	15.30	2.75	0.04	0.84
14	G4/X	D	66.47	0.48	16.79	3.46	0.10	1.00
15	G6/Z	A	68.48	0.43	15.58	2.98	0.05	0.95
16	G5/Y	B	61.92	0.74	16.44	5.71	0.12	2.82
17	NA/Q	A	68.48	0.44	15.86	2.91	0.05	0.91
18	NA/Q	Q	54.10	2.30	14.91	13.44	0.19	2.35

Table 7: Major elements used for multidimensional scaling from selected lithic flakes. (continued).

Flake No.	CaO	Na_2O	K_2O	P_2O_5	LOI	Total
1	2.78	3.87	4.13	0.15	0.4	99.70
2	4.64	3.65	3.02	0.16	0.1	99.70
3	2.81	3.66	3.96	0.15	0.4	99.69
4	3.14	4.78	3.35	0.27	0.1	99.65
5	2.83	3.97	4.18	0.15	0.1	99.79
6	2.37	4.86	3.72	0.22	0.2	99.61
7	2.87	3.89	4.14	0.17	0.3	99.67
8	4.59	3.63	2.96	0.17	0.1	99.59
9	5.22	3.55	2.66	0.14	0.2	99.63
10	3.07	4.86	3.37	0.27	0.2	99.79
11	3.47	4.24	3.20	0.18	0.1	99.66
12	4.16	4.66	2.53	0.26	0.1	99.92
13	2.57	3.98	4.06	0.14	0.2	99.83
14	2.87	4.81	3.36	0.25	0.2	99.79
15	2.83	4.02	4.06	0.15	0.3	99.83
16	4.33	4.48	2.99	0.27	0.1	99.92
17	2.84	3.91	4.11	0.14	0.3	99.95
18	5.98	3.61	2.69	1.08	-0.8	99.70

Table 8: Trace and rare earth elements used for multidimensional scaling from selected lithic flakes.

Flake No.	Rb	Cs	Sr	Ba	Zr	Hf	Ta	Nb	Th	U	La
1	134	2.8	375	1170	201	5.3	0.7	8.2	13.0	5.1	26.3
2	79	2.6	366	1956	187	5.2	0.6	7.5	7.1	3.1	23.8
3	138	4.9	376	1187	197	5.5	0.7	7.8	12.4	4.8	25.9
4	91	3.3	526	1381	230	5.9	0.7	10.9	6.4	3.4	28.0
5	133	2.8	373	1310	201	5.9	0.9	8.3	12.6	5.0	29.4
6	104	3.0	487	1562	295	7.2	0.7	11.9	7.9	3.6	29.7
7	129	2.9	364	1318	199	5.5	0.7	7.9	11.8	4.8	28.1
8	75	2.6	348	1942	180	4.8	0.6	7.3	7.3	3.1	23.2
9	68	2.3	329	1639	157	4.5	0.5	6.3	6.8	2.5	20.0
10	89	3.3	517	1354	216	6.0	0.7	10.1	6.6	3.2	27.1
11	82	2.6	633	1237	133	3.6	0.3	3.7	5.6	2.8	17.6
12	60	1.7	569	813	159	4.4	0.3	4.8	6.4	2.9	19.4
13	142	3.4	385	1313	205	5.8	0.7	8.6	14.7	5.2	26.7
14	88	2.9	503	1360	230	6.4	0.7	10.4	6.7	3.3	28.0
15	132	2.9	388	1204	202	5.7	0.7	8.3	14.2	4.8	25.7
16	68	2.1	473	1155	161	4.7	0.6	9.9	5.1	2.4	25.9
17	132	3.0	382	1226	199	5.5	0.7	7.7	14.2	5.0	28.6
18	53	0.3	472	912	419	11.0	2.5	42.3	4.7	1.5	48.9

Table 8: Trace and rare earth elements used for multidimensional scaling from selected lithic flakes. (continued).

Flake No.	Ce	Pr	Nd	Sm	Eu	Gd	Tb	Dy	Ho	Er
1	52.1	6.00	23.1	3.9	0.88	2.70	0.39	2.13	0.37	1.07
2	46.1	5.33	21.4	3.7	1.25	3.53	0.55	3.22	0.63	1.97
3	51.0	5.90	22.5	3.5	0.84	2.57	0.41	2.13	0.39	1.20
4	58.7	7.28	30.4	5.2	1.40	3.96	0.64	3.19	0.59	1.83
5	57.6	6.92	26.9	4.4	0.99	2.92	0.39	2.09	0.39	1.09
6	61.1	7.38	30.3	5.0	1.39	3.61	0.56	3.08	0.54	1.75
7	55.9	6.40	25.8	4.0	0.94	2.76	0.44	2.26	0.37	1.19
8	45.2	5.30	21.0	4.1	1.20	3.60	0.59	3.53	0.70	2.21
9	39.8	4.58	18.7	3.6	1.05	3.29	0.54	3.32	0.60	1.93
10	57.3	7.09	29.0	5.3	1.47	3.98	0.62	3.47	0.60	1.83
11	36.2	4.26	17.7	2.8	0.77	1.84	0.24	1.13	0.17	0.44
12	41.6	5.15	20.7	3.6	1.01	2.76	0.37	1.81	0.29	0.77
13	54.6	6.19	23.2	4.1	0.87	2.75	0.40	2.17	0.36	1.09
14	60.8	7.33	29.6	5.3	1.32	4.18	0.65	3.47	0.57	1.78
15	53.4	6.17	24.9	3.8	0.90	2.82	0.46	2.22	0.36	1.09
16	58.2	7.26	29.5	5.4	1.48	4.57	0.70	3.88	0.63	1.89
17	58.4	6.39	23.4	3.8	0.81	2.74	0.43	2.08	0.39	1.10
18	125.8	15.23	67.6	13.8	3.22	12.61	2.09	9.90	1.78	4.97

Table 8: Trace and rare earth elements used for multidimensional scaling from selected lithic flakes. (continued).

Flake No.	Tm	Yb	Lu	Y	Ga	V	Cr	Sc	Ni
1	0.17	0.96	0.16	11.7	16.8	54	14	6	
2	0.30	2.13	0.32	19.3	17.6	93	68	13	17
3	0.16	1.10	0.17	11.6	17.6	68	68	8	8
4	0.27	1.96	0.30	19.4	18.1	27		5	
5	0.16	1.02	0.16	11.7	16.9	53		6	
6	0.29	1.73	0.31	18.4	18.4	12	7	3	
7	0.16	1.08	0.16	12.4	16.6	53	7	6	
8	0.34	2.19	0.34	20.4	16.4	88	68	13	18
9	0.29	1.96	0.30	18.6	16.7	103	89	15	35
10	0.26	1.77	0.27	18.7	18.1	27		5	
11	0.07	0.40	0.05	5.4	19.7	70	27	6	15
12	0.10	0.78	0.10	8.6	20.9	92	62	9	25
13	0.15	1.03	0.16	11.5	18.7	54	14	5	8
14	0.26	1.70	0.28	17.9	18.7	22	7	4	8
15	0.16	1.01	0.16	11.2	18.3	58	7	6	10
16	0.27	1.70	0.27	19.6	18.5	108	96	11	36
17	0.17	1.06	0.16	12.4	17.7	58	10	6	11
18	0.71	4.22	0.60	54.7	27.2	110	12	18	15

Table 8: Trace and rare earth elements used for multidimensional scaling from selected lithic flakes. (continued).

Flake No.	Co	Zn	Cu	Pb	Mo	As	W
1	5.5	17	7.9	2.2	0.3	3.9	1.1
2	16.9	22	15.2	5.9	0.3	3.6	0.7
3	6.3	24	6.5	1.4	0.4	3.4	1.6
4	3.5	35	3.9	1.7	0.3	2.0	0.9
5	5.5	14	6.5	1.8	0.2	2.6	1.4
6	1.2	28	3.0	1.2	0.2	2.6	0.9
7	5.8	26	5.7	2.8	0.3	7.2	1.8
8	15.7	9	9.6	1.3	0.3	1.8	0.6
9	19.4	17	10.5	1.6	0.4	3.2	0.6
10	3.8	54	7.6	2.7	0.4	2.6	0.8
11	8.9	10	6.0	0.7	0.2	2.4	0.3
12	12.0	16	17.0	0.8	0.1	1.5	0.6
13	5.1	10	2.7	0.6	0.2	2.4	1.0
14	3.6	45	6.7	4.0	0.5	4.3	1.0
15	5.5	17	6.3	2.0	0.2	2.0	1.0
16	17.7	27	22.6	1.1	0.4	2.0	1.0
17	5.6	7	4.6	0.3	0.1	nd	1.1
18	24.0	80	5.9	0.3	0.4	nd	1.0

APPENDIX V: VARIATION TESTING OF SELECTED LITHIC FLAKES

Table 9: Major elements for variation testing of selected samples.
Concentrations in different locations of each lithic Flake 17 (Geo 1-7 and Geo 10-11) and 18 (Geo 8-9 and Geo 12-13). (Quantities expressed in wt %)

ELEMENT	SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	Na_2O	K_2O	TiO_2	P_2O_5
Flake No./Sample	**wt %**	**wt %**	**wt %**	**wt %**	**wt %**	**wt %**	**wt %**	**wt %**	**wt %**
17/Geo-1	68.32	16.02	2.96	0.92	2.84	3.9	4.12	0.44	0.14
17/Geo-2	68.55	15.67	2.94	0.92	2.84	3.87	4.1	0.44	0.14
17/Geo-3	68.28	15.97	2.89	0.91	2.81	3.94	4.09	0.44	0.14
17/Geo-4	68.7	15.65	2.94	0.91	2.85	3.89	4.08	0.44	0.14
17/Geo-5	68.3	15.81	2.9	0.91	2.9	3.9	4.16	0.44	0.14
17/Geo-6	68.64	15.8	2.9	0.9	2.81	3.94	4.14	0.44	0.14
17/Geo-7	68.21	15.96	2.92	0.9	2.82	3.93	4.08	0.44	0.14
18/Geo-8	54.08	14.95	13.56	2.38	5.99	3.6	2.72	2.32	1.09
18/Geo-9	53.97	14.95	13.34	2.33	5.96	3.62	2.68	2.29	1.06
18/RETEST Geo-9	54.13	14.87	13.45	2.34	5.96	3.59	2.7	2.27	1.09
17/Geo-10	68.73	15.88	2.88	0.89	2.88	3.91	4.15	0.44	0.14
17/Geo-11	68.57	15.99	2.88	0.89	2.81	3.92	4.08	0.44	0.13
18/Geo-12	54.49	14.94	13.27	2.32	5.98	3.63	2.7	2.29	1.07
18/Geo-13	53.85	14.82	13.59	2.4	6.02	3.62	2.67	2.34	1.07

Table 9: Major elements for variation testing of selected samples (continued).
Concentrations in different locations of each lithic Flake 17 (Geo 1-7, and Geo 10-11) and 18 (Geo 8-9, and Geo 12-13). (Quantities expressed in wt%) (Continued)

ELEMENT	MnO	Cr_2O_3	Ni	Sc	LOI	TOT/C	TOT/S	SUM
Flake No./Sample	**wt %**	**wt %**	**ppm**	**ppm**	**%**	**%**	**%**	**%**
17/Geo-1	0.05	0.001	7	6	0.1	0.01	0.01	99.82
17/Geo-2	0.05	0.002	10	6	0.3	0.01	0.01	99.83
17/Geo-3	0.05	0.001	6	6	0.3	0.01	0.02	99.82
17/Geo-4	0.05	0.001	7	6	0.3	0.01	0.01	99.96
17/Geo-5	0.05	0.001	13	6	0.3	0.01	0.01	99.82
17/Geo-6	0.05	0.001	9	6	0.2	0.01	0.01	99.97
17/Geo-7	0.05	0.002	12	6	0.5	0.02	0.01	99.96
18/Geo-8	0.19	0.002	11	19	-1	0.01	0.04	99.88
18/Geo-9	0.19	0.002	12	18	-0.5	0.02	0.05	99.89
18/RETEST Geo-9	0.19	0.003	15	19	-0.7	0.01	0.05	99.9
17/Geo-10	0.05	0.003	19	5	0.1	0.01	0.01	100.06
17/Geo-11	0.05	0.001	15	6	0.2	0.02	0.03	99.97
18/Geo-12	0.19	0.001	10	18	-1	0.02	0.05	99.88
18/Geo-13	0.19	0.001	27	18	-0.7	0.03	0.06	99.88

Table 10: Trace and rare earth elements for variation testing of selected samples.
Concentrations in different locations of each lithic flake 17 (Geo 1-7, and Geo 10-11) and 18 (Geo 8-9, and Geo 12-13) for selected Punchaw Lake Village site samples. (Quantities expressed in ppm)

ELEMENT	Ba	Be	Co	Cs	Ga	Hf	Nb	Rb	Sn	Sr	Ta
Flake No./Sample	**ppm**	**ppm**	**ppm**	**ppm**	**ppm**	**ppm**	**ppm**	**ppm**	**ppm**	**ppm**	**ppm**
17/Geo-1	1186.6	1	5.8	3	17.9	5.7	7.6	132.7	1	385.1	0.7
17/Geo-2	1230.9	1	5.8	2.9	17.1	5.6	7.9	132.7	1	385.6	0.7
17/Geo-3	1200.1	1	5.4	3	17.5	5.5	7.6	129.4	1	374.1	0.6
17/Geo-4	1227.2	2	5.7	3	18.2	5.5	7.7	134.9	1	387.5	0.6
17/Geo-5	1207.7	1	5.7	2.9	17.3	5.8	7.5	128.3	1	379.3	0.7
17/Geo-6	1252.7	2	5.7	3.1	18.2	5.5	7.6	131.4	1	382.1	0.6
17/Geo-7	1218.2	1	5.3	3	17	5.4	7.6	131.8	1	380.1	0.6
18/Geo-8	888.7	2	23.3	0.3	28.2	10.4	41.9	52.7	3	471.7	2.5
18/Geo-9	928.9	2	24.5	0.3	26.5	10.7	42.7	53	3	471.3	2.5
18/RETEST Geo-9	923.3	2	24.9	0.3	28.3	11.7	44	54.1	4	479.2	2.6
17/Geo-10	1265.8	1	5.6	2.9	17.8	5.4	8.2	132.7	1	376.4	1.4
17/Geo-11	1247.5	1	5.5	3	18	5.5	7.8	134.1	1	386.9	0.7
18/Geo-12	906	2	23.3	0.3	26.4	11.2	41.9	52.2	3	469.8	2.5
18/Geo-13	912	3	24.1	0.2	26.8	10.9	41.2	52.4	3	466.3	2.4

Table 10: Trace and rare earth elements for variation testing of selected samples (continued). Concentrations in different locations of each lithic flake 17 (Geo 1-7, and Geo 10-11) and 18 (Geo 8-9, and Geo 12-13) for selected Punchaw Lake Village site samples. (Quantities expressed in ppm) Continued

ELEMENT	Th	U	V	W	Zr	Y	La	Ce	Pr	Nd	Sm
Flake No./Sample	**ppm**	**ppm**	**ppm**	**ppm**	**ppm**	**ppm**	**ppm**	**ppm**	**ppm**	**ppm**	**ppm**
17/Geo-1	15.5	5.1	60	2.1	198.8	12.3	27.9	58	6.41	23.1	3.7
17/Geo-2	14.7	4.9	60	1.8	201.3	12.5	28.8	59.2	6.44	23.6	3.7
17/Geo-3	14.1	4.8	58	0.9	193.9	11.9	28.2	57.6	6.3	23.2	3.8
17/Geo-4	14.4	5.2	59	0.8	198.4	12.4	28.7	58.9	6.39	23.5	3.8
17/Geo-5	15.4	4.9	57	0.9	198.1	12.2	28	57	6.22	22.4	3.7
17/Geo-6	13.6	5.2	57	0.9	199.2	12.2	29.1	59.6	6.46	24.5	3.7
17/Geo-7	13.4	4.8	57	0.8	197	12.5	28.4	57.8	6.28	22.7	3.8
18/Geo-8	5.3	1.6	111	1	418	55	47.8	122.6	15.07	67.5	13.7
18/Geo-9	4.9	1.5	112	1.1	418.8	54.5	49	128.3	15.47	67.9	13.7
18/RETEST Geo-9	4.3	1.5	111	1.2	427.8	55.7	49.5	126.3	15.57	69.7	14
17/Geo-10	13.9	5.3	56	1	200.5	12.5	29.5	59.3	6.51	23.4	3.9
17/Geo-11	13.2	5.1	56	1	204.9	12.7	29	58.6	6.51	24.4	3.7
18/Geo-12	4.8	1.4	109	1	415.6	54.3	48.9	124.6	15.04	67.8	13.8
18/Geo-13	4.2	1.5	108	0.9	413.1	54.2	49.1	127.4	15	65	13.7

Table 10: Trace and rare earth elements for variation testing of selected samples (continued). Concentrations in different locations of each lithic flake 17 (Geo 1-7, and Geo 10-11) and 18 (Geo 8-9, and Geo 12-13) for selected Punchaw Lake Village site samples. (Quantities expressed in ppm)

ELEMENT	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu	Mo	Cu
Flake No./Sample	**ppm**	**ppm**	**ppm**	**ppm**	**ppm**	**ppm**	**ppm**	**ppm**	**ppm**	**ppm**	**ppm**
17/Geo-1	0.83	2.68	0.44	2.05	0.38	1.05	0.17	1.09	0.17	0.1	4.8
17/Geo-2	0.82	2.76	0.44	2.03	0.4	1.13	0.18	1.08	0.16	0.1	4.6
17/Geo-3	0.78	2.7	0.42	2.07	0.4	1.07	0.18	1.05	0.16	0.1	5
17/Geo-4	0.83	2.77	0.43	2.01	0.39	1.05	0.18	1.03	0.16	0.1	4
17/Geo-5	0.8	2.63	0.42	2.06	0.38	1.13	0.18	1.03	0.16	0.1	4.7
17/Geo-6	0.84	2.82	0.45	2.09	0.39	1.11	0.18	1.09	0.16	0.1	4.6
17/Geo-7	0.76	2.64	0.41	2.11	0.37	1.08	0.17	1.01	0.15	0.1	5.9
18/Geo-8	3.16	12.43	2.06	9.58	1.7	4.96	0.71	4.14	0.63	0.4	5.3
18/Geo-9	3.24	12.51	2.12	9.84	1.8	5.05	0.72	4.32	0.59	0.4	4.8
18/RETEST Geo-9	3.31	13.02	2.13	10.02	1.82	5	0.72	4.4	0.61	0.3	4.9
17/Geo-10	0.8	2.81	0.44	2.12	0.39	1.1	0.16	1.09	0.15	0.1	4.4
17/Geo-11	0.83	2.85	0.44	2.21	0.37	1.15	0.17	1.1	0.16	0.1	3.2
18/Geo-12	3.2	12.6	2.08	10.11	1.75	4.85	0.7	4.13	0.59	0.5	7.3
18/Geo-13	3.17	12.47	2.08	9.95	1.84	4.97	0.71	4.11	0.6	0.5	7.2

Table 10: Trace and rare earth elements for variation testing of selected samples (continued). Concentrations in different locations of each lithic flake 17 (Geo 1-7, and Geo 10-11) and 18 (Geo 8-9, and Geo 12-13) for selected Punchaw Lake Village site samples. (Quantities expressed in ppm)

ELEMENT	Pb	Zn	Ni	As	Cd	Sb	Bi	Ag	Au	Hg	Tl	Se
Flake No./Sample	**ppm**	**ppm**	**ppm**	**ppm**	**ppm**	**ppm**	**ppm**	**ppm**	**ppb**	**ppm**	**ppm**	**ppm**
17/Geo-1	0.4	7	0.4	<.5	<.1	<.1	<.1	<.1	19.1	<.01	<.1	<.5
17/Geo-2	0.2	7	0.3	<.5	<.1	<.1	<.1	<.1	35.8	<.01	<.1	<.5
17/Geo-3	0.3	7	0.4	<.5	<.1	<.1	<.1	<.1	22.2	<.01	<.1	<.5
17/Geo-4	0.3	7	0.3	<.5	<.1	<.1	<.1	<.1	16.8	<.01	<.1	<.5
17/Geo-5	0.2	6	0.3	<.5	<.1	<.1	<.1	<.1	21.8	<.01	<.1	<.5
17/Geo-6	0.2	7	0.4	<.5	<.1	<.1	<.1	<.1	52.5	<.01	<.1	<.5
17/Geo-7	0.2	8	0.5	<.5	<.1	<.1	<.1	<.1	89.4	<.01	<.1	<.5
18/Geo-8	0.2	73	2.4	<.5	0.1	<.1	<.1	<.1	19.1	<.01	<.1	<.5
18/Geo-9	0.3	72	2	<.5	<.1	<.1	<.1	<.1	28.3	<.01	<.1	<.5
18/RETEST Geo-9	0.3	69	2.1	<.5	<.1	<.1	<.1	<.1	16.9	<.01	<.1	<.5
17/Geo-10	0.3	7	0.4	<.5	<.1	<.1	<.1	<.1	9.5	<.01	<.1	<.5
17/Geo-11	0.2	8	0.4	<.5	<.1	<.1	<.1	<.1	5.2	<.01	<.1	<.5
18/Geo-12	0.4	94	2.8	<.5	0.1	<.1	<.1	<.1	13	<.01	<.1	<.5
18/Geo-13	0.4	90	2.6	<.5	0.1	<.1	<.1	<.1	5.7	<.01	<.1	<.5

APPENDIX VI: PRECISION, ACCURACY, DETECTION LIMITS AND ARTIFACT CHEMICAL VARIATION

Precision and accuracy are generally better than 1% for the major elements oxides. Most trace elements have precision and accuracy better than 5% except Ta, Zn, Cu (<10%),

Ni (15%), Cr, Pb, and W (30-45%). Variation on the composition of three powders from different parts of one artifact is essentially the same as precision estimates.

Notes: Major element oxides in wt. %. All trace and rare earth elements in ppm.

Nd = not detected.

Mean = average of 6 analyses from splits of one powder for sample 2761.

SDP = Standard Deviation for calculating Precision on the Mean

Precision % = (SDP/Mean)*100

Av. Std. = average of two analyses of standard.

Std. Accept. = Accepted literature values for the standard. Elements determined by aquaregia leach = Zn, Cu, Pb, Mo, As and standard run with samples = DS7. All other elements run with standard SO18 (Refer to Appendix VI).

Accuracy = the absolute value of ((Av. Std. - Std. Accept.)/Std. Accept.)*100

Det. Lim. = Detection Limit.

Av.17 = Average of all powders chemically tested for flake No. 17. Three powders were made from different portions of flake No. 17. One powder was analyzed 6 times, a second powder was analyzed once and a third powder twice. This is the average of the average for powder 1, the single analyses of powder 2, and the average for powder 3.

SD 17 = standard deviation on the mean for the 3 powders from sample 17.

Variation % = percentage variation between 3 powders from one artifact (17)

Table 11: Precision, accuracy, detection limits and artifact chemical variation of selected lithic flakes.

Precision Estimate							
ELEMENT	**SiO_2**	**TiO_2**	**Al_2O_3**	**Fe_2O_3**	**MnO**	**MgO**	**CaO**
Mean (n=6)	68.47	0.44	15.82	2.92	0.05	0.91	2.84
SDP	0.19	0.00	0.15	0.03	0.00	0.01	0.03
Precision %	0.27	0.00	0.96	0.98	0.00	0.83	1.2
Accuracy Estimate							
Av Std.	58.20	0.69	14.14	7.64	0.39	3.34	6.39
Std. Accept.	58.47	0.69	14.23	7.67	0.39	3.35	6.42
Accuracy %	0.47	0.00	0.67	0.39	0.00	0.30	0.55
Detection Limits from ACME Analytical							
Det. Lim.	0.04	0.01	0.03	0.04	0.01	0.01	0.01
Variation Estimate							
Av. 17	68.44	0.44	15.91	2.91	0.05	0.90	2.84
SD 17	0.22	0.00	0.07	0.02	0.00	0.01	0.01
Variation %	0.32	0.00	0.47	0.81	0.00	1.20	0.48

Table 11: Precision, accuracy, detection limits and artifact chemical variation of selected lithic flakes. (continued).

Precision Estimate								
ELEMENT	**Na_2O**	**K_2O**	**P_2O_5**	**Rb**	**Cs**	**Sr**	**Ba**	**Zr**
Mean (n=6)	3.91	4.12	0.14	131.6	2.98	382.3	1218	198.3
SDP	0.03	0.03	0.00	2.4	0.08	4.9	24	2.4
Precision %	0.72	0.75	0.00	1.8	2.5	1.3	2.0	1.2
Accuracy Estimate								
Av Std.	3.69	2.18	0.83	28.1	7.0	412.4	513.5	290.8
Std. Accept.	3.71	2.17	0.83	28.7	7.1	407.4	514	280
Accuracy %	0.67	0.23	0.00	2.3	2.1	1.2	0.10	3.8
Detection Limits from ACME Analytical								
Det. Lim.	0.01	0.04	0.01	0.5	0.1	0.5	0.5	0.5
Variation Estimate								
Av. 17	3.92	4.10	0.14	132.3	2.98	381.3	1231	199.3
SD 17	0.01	0.02	0.00	1.0	0.03	1.1	22	3.0
Variation %	0.30	0.49	2.09	0.75	0.85	0.29	1.8	1.5

Table 11: Precision, accuracy, detection limits and artifact chemical variation of selected lithic flakes. (continued).

Precision Estimate								
ELEMENT	**Hf**	**Ta**	**Nb**	**Th**	**U**	**La**	**Ce**	**Pr**
Mean (n=6)	5.60	0.65	7.65	14.62	5.02	28.45	58.38	6.370
SDP	0.13	0.05	0.14	0.74	0.17	0.48	1.01	0.092
Precision %	2.3	8.4	1.8	5.1	3.4	1.7	1.7	1.4
Accuracy Estimate								
Av Std.	9.9	7.2	21.0	10.1	16.3	11.9	27.6	3.40
Std. Accept.	9.8	7.4	20.9	9.9	16.4	12.3	27.1	3.45
Accuracy %	0.51	3.4	0.24	2.0	0.91	3.7	1.8	1.6
Detection Limits from ACME Analytical								
Det. Lim.	0.5	0.1	0.5	0.1	0.1	0.5	0.5	0.02
Variation Estimate								
Av. 17	5.48	0.77	7.75	13.86	5.01	28.70	58.38	6.387
SD 17	0.10	0.25	0.22	0.66	0.20	0.48	0.58	0.116
Variation %	1.9	32	2.8	4.8	4.0	1.7	0.98	1.8

Table 11: Precision, accuracy, detection limits and artifact chemical variation of selected lithic flakes. (continued).

Precision Estimate								
ELEMENT	**Nd**	**Sm**	**Eu**	**Gd**	**Tb**	**Dy**	**Ho**	**Er**
Mean (n=6)	23.38	3.733	0.817	2.727	0.433	2.052	0.390	1.090
SDP	0.69	0.052	0.023	0.069	0.012	0.029	0.009	0.038
Precision %	3.0	1.4	2.8	2.5	2.8	1.4	2.3	3.5
Accuracy Estimate								
Av Std.	13.9	2.9	0.86	2.88	0.54	3	0.60	1.8
Std. Accept.	14	3	0.89	2.93	0.53	3	0.62	1.84
Accuracy %	1.1	3.3	3.4	1.9	1.9	0.0	4.0	2.2
Detection Limits from ACME Analytical								
Det. Lim.	0.4	0.1	0.05	0.05	0.01	0.05	0.05	0.05
Variation Estimate								
Av. 17	23.33	3.778	0.797	2.732	0.428	2.109	0.380	1.098
SD 17	0.60	0.038	0.032	0.095	0.016	0.057	0.010	0.024
Variation %	2.6	1.0	4.0	3.5	3.7	2.7	2.6	2.2

Table 11: Precision, accuracy, detection limits and artifact chemical variation of selected lithic flakes. (continued).

Precision Estimate								
ELEMENT	**Tm**	**Yb**	**Lu**	**Y**	**Ga**	**V**	**Cr**	**Sc**
Mean (n=6)	0.178	1.062	0.162	12.25	17.70	58.5	8.0	6
SDP	0.004	0.029	0.004	0.21	0.47	1.4	2.8	0
Precision %	2.3	2.7	2.5	1.7	2.6	2.4	35	0.0
Accuracy Estimate								
Av Std.	0.29	1.72	0.27	32.1	17.5	203.5	3760	25
Std. Accept.	0.29	1.79	0.27	33	17.6	200	3760	25
Accuracy %	1.7	3.9	1.9	2.7	0.57	1.8	0.0	2.0
Detection Limits from ACME Analytical								
Det. Lim.	0.05	0.05	0.01	0.1	0.5	5	7	1
Variation Estimate								
Av. 17	0.171	1.056	0.156	12.45	17.53	57.2	11.8	5.8
SD 17	0.007	0.043	0.006	0.18	0.47	1.3	3.3	0.3
Variation %	3.9	4.1	3.8	1.4	2.7	2.2	28	4.9

Table 11: Precision, accuracy, detection limits and artifact chemical variation of selected lithic flakes. (continued).

Precision Estimate								
ELEMENT	**Ni**	**Co**	**Zn**	**Cu**	**Pb**	**Mo**	**As**	**W**
Mean (n=6)	0.350	5.68	6.8	4.62	0.27	0.10	nd	1.23
SDP	0.055	0.15	0.4	0.34	0.08	0.00		0.56
Precision %	16	2.6	6.0	7.3	31	0.0		46
Accuracy Estimate								
Av Std.	43	27.1	393	108	68.0	21.2	48.5	15.1
Std. Accept.	44	26.2	411	109	70.6	20.92	48.2	15.1
Accuracy %	3.4	3.4	4.5	1.3	3.8	1.3	0.52	0.0
Detection Limits from ACME Analytical								
Det. Lim.	30	20	20	0.01	0.1	0.01	0.1	0.1
Variation Estimate								
Av. 17	0.417	5.51	7.4	4.77	0.24	0.1	nd	1.01
SD 17	0.076	0.19	0.6	1.06	0.03	0		0.22
Variation %	18	3.5	7.9	22	15	0		21

APPENDIX VII: ELEMENT STANDARDS TABLES

Table 12: SO-18 Internal Reference Material for Whole Rock Analysis

AcmeLabs ACME ANALYTICAL LABORATORIES LTD.

CERTIFICATE OF ANALYSIS

SO-18

Internal Reference Material for Whole Rock Analysis

Element	Group 4A Detection Limit	Unit	SO-18 Expected Value	SO-18 Upper Limit	SO-18 Lower Limit
SiO_2	0.04	%	**58.47**	60.22	56.72
Al_2O_3	0.03	%	**14.23**	14.66	13.80
Fe_2O_3	0.04	%	**7.67**	7.90	7.44
MgO	0.01	%	**3.35**	3.45	3.25
CaO	0.01	%	**6.42**	6.61	6.23
Na_2O	0.01	%	**3.71**	3.82	3.60
K_2O	0.04	%	**2.17**	2.28	2.06
TiO_2	0.01	%	**0.69**	0.73	0.65
P_2O_5	0.01	%	**0.83**	0.87	0.79
MnO	0.01	%	**0.39**	0.42	0.36
Cr_2O_3	0.001	%	**0.550**	0.567	0.534
Ba	5	ppm	**515**	541	489
Ni	30	ppm	**44**	52	20
Sr	10	ppm	**402**	442	362
Zr	10	ppm	**280**	308	252
Y	10	ppm	**33**	35	25
Sc	1	ppm	**25**	28	20
LOI	0.1	%	**1.9**	2.1	1.7
Ce	20	ppm	**27**	40	<20
Co	20	ppm	**25**	40	<20
Cu	20	ppm	**66**	73	59
Nb	20	ppm	**21**	40	<20
Ta	20	ppm	**<20**		
Zn	20	ppm	**40**	48	32
C*	0.01	%	**3.13**	3.05	3.21
S*	0.01	%	**4.19**	4.11	4.27

Element	Group 4B Detection Limit	Unit	SO-18 Official Value	SO-18 Upper Limit	SO-18 Lower Limit
Ba	0.5	ppm	**514.0**	565.4	462.6
Be	1	ppm	**1.0**	3.0	<1
Co	0.5	ppm	**26.2**	28.8	23.6
Cs	0.1	ppm	**7.1**	7.9	6.3
Ga	0.5	ppm	**17.6**	19.4	15.8
Hf	0.5	ppm	**9.8**	10.8	8.8
Nb	0.5	ppm	**20.9**	23.0	18.8
Rb	0.5	ppm	**28.7**	31.6	25.8
Sn	1	ppm	**15**	20.0	12.0
Sr	0.5	ppm	**407.4**	448.1	366.7
Ta	0.1	ppm	**7.4**	8.1	6.7
Th	0.1	ppm	**9.9**	10.9	8.9
U	0.1	ppm	**16.4**	18.0	14.8
V	5	ppm	**200**	220	180
W	0.1	ppm	**15.1**	17.4	12.8
Zr	0.5	ppm	**280.0**	308.0	252.0
Y	0.1	ppm	**33.0**	36.3	29.7
La	0.5	ppm	**12.3**	14.1	10.5
Ce	0.5	ppm	**27.1**	29.8	24.4
Pr	0.02	ppm	**3.45**	3.8	3.1
Nd	0.4	ppm	**14.0**	15.4	12.6
Sm	0.1	ppm	**3.0**	3.4	2.6
Eu	0.05	ppm	**0.89**	0.98	0.80
Gd	0.05	ppm	**2.93**	3.22	2.64
Tb	0.01	ppm	**0.53**	0.58	0.48
Dy	0.05	ppm	**3.00**	3.30	2.70
Ho	0.05	ppm	**0.62**	0.68	0.56
Er	0.05	ppm	**1.84**	2.02	1.66
Tm	0.05	ppm	**0.29**	0.32	0.26
Yb	0.05	ppm	**1.79**	1.97	1.61
Lu	0.01	ppm	**0.27**	0.30	0.24

* C and S values for STD CSC by Leco Analysis

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SO18 COAv1 3 First issued: April 19, 2005 Revision Date of this Certificate: Feb 20, 2007

Table 13: DS7 Internal Reference Material for Geochem Aqua Regia Digestion

AcmeLabs ACME ANALYTICAL LABORATORIES LTD.

CERTIFICATE OF ANALYSIS

DS7

Internal Reference Material for Geochem Aqua Regia Digestion

ELEMENT	Unit	Group 1F Detection Limit	Expected Value	Standard Deviation*
Au	ppb	0.2	70.0	30.0
Ag	ppb	2	890	85
Al	%	0.01	0.959	0.072
As	ppm	0.1	48.2	4.7
B	ppm	1	38.6	3.6
Ba	ppm	0.5	370.3	25.7
Bi	ppm	0.02	4.51	0.27
Ca	%	0.01	0.930	0.06
Cd	ppm	0.01	6.38	0.49
Co	ppm	0.1	9.7	0.74
Cr*	ppm	0.5	163	12
Cu	ppm	0.01	109	10.1
Fe	%	0.01	2.39	0.15
Ga	ppm	0.1	4.6	0.3
Hg	ppb	5	200	13
K	%	0.01	0.44	0.03
La	ppm	0.5	12.7	1.2
Mg	%	0.01	1.05	0.07
Mn	ppm	1	627	42
Mo	ppm	0.01	20.92	1.69
Na	%	0.001	0.073	0.007
Ni	ppm	0.1	56.0	4.0
P	%	0.001	0.080	0.006
Pb	ppm	0.01	70.60	5.01
S	%	0.02	0.21	0.01
Sb	ppm	0.02	5.86	0.47
Sc	ppm	0.1	2.5	0.2
Se	ppm	0.1	3.5	0.2
Sr	ppm	0.5	68.7	5.8
Te	ppm	0.02	1.08	0.07
Th	ppm	0.1	4.4	0.38
Ti	%	0.001	0.124	0.01
Tl	ppm	0.02	4.19	0.34
U	ppm	0.1	4.9	0.4
V	ppm	2	86	6.7
W	ppm	0.1	3.8	0.2
Zn	ppm	0.1	411.0	23.9

ELEMENT	Unit	Detection Limit	Expected Value	Standard Deviation*
Optional Elements				
Be	ppm	0.1	1.6	0.19
Ce	ppm	0.1	38.0	3.6
Cs	ppm	0.02	6.36	0.60
Ge	ppm	0.1	0.1	0.03
Hf	ppm	0.02	0.11	0.01
In	ppm	0.02	1.57	0.11
Li	ppm	0.1	29.3	2.1
Nb	ppm	0.02	0.71	0.12
Rb	ppm	0.1	35.8	2.4
Re	ppb	1	4	1
Sn	ppm	0.1	5.4	1.1
Ta	ppm	0.05	<0.05	
Y	ppm	0.01	5.18	0.63
Zr	ppm	0.1	5.4	0.38
Pt	ppb	2	37	3
Pd	ppb	10	58	11
Rare Earth Elements (Provisional Values)				
Pr	ppm	0.02	1.92	
Nd	ppm	0.02	9.38	
Sm	ppm	0.02	1.02	
Eu	ppm	0.02	0.27	
Gd	ppm	0.02	1.15	
Tb	ppm	0.01	0.16	
Dy	ppm	0.02	0.94	
Ho	ppm	0.02	0.19	
Er	ppm	0.02	0.55	
Tm	ppm	0.01	0.08	
Yb	ppm	0.01	0.54	
Lu	ppm	0.02	0.09	

Based on Mass Spec Analysis Subject to Change With Additional Testing

* Elemental variation due to pulverizer contamination

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